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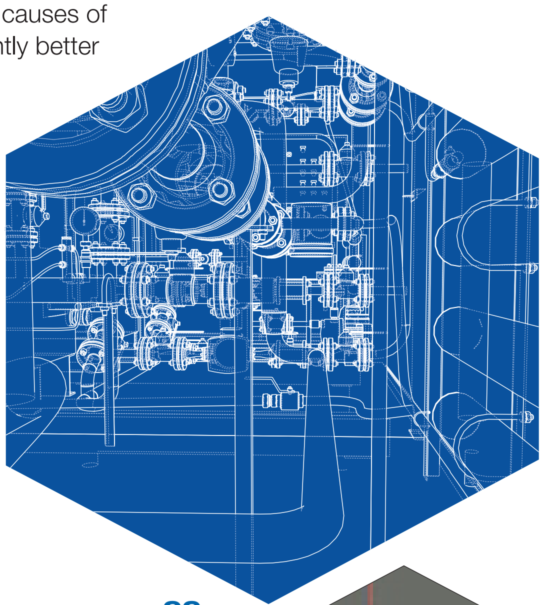
Cover Story

In the News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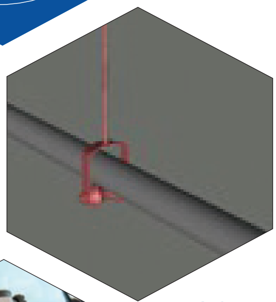
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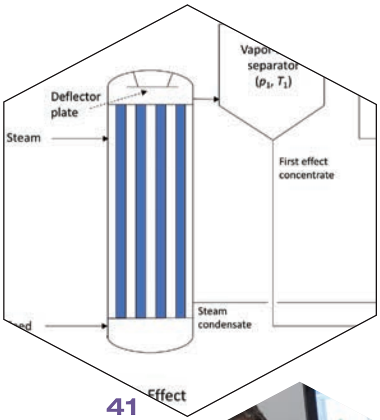
Technical and Practical



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Cover design: Tara Bekman

CHEMICAL ENGINEERING
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Editor's Page

Introducing CE Voices

As we continue to bring a variety of articles and news to the pages of *Chemical Engineering*, we also offer a growing online presence with additional resources for our readers to stay in touch with what is going on in the chemical process industries (CPI).

Many of you are already familiar with our website, with its up-to-date Latest News items, exclusive articles and much more. We have recently added a new feature called CE Voices.

CE Voices

CE Voices is a series of short video interviews. These insightful conversations led by our editors cover a broad range of topics that are of interest to professionals in the CPI. Our first group of videos, which you can currently find on our website (www.chemengonline.com; type "CE Voices" into the search box), includes the following topics. We hope you find them interesting and useful.

Industry Analysis from Deloitte — Duane Dickson, vice chairman and U.S. Oil, Gas & Chemicals sector leader for Deloitte Consulting LLP, discusses topics related to a recent mid-year analysis from Deloitte on the outlook for the oil, gas and chemical industries. Dickson addresses how the CPI is pivoting production to meet specific needs caused by the pandemic and considerations that will continue to affect production — like consumption changes that may create new demands, and changes in travel patterns that are influencing fuel needs. The interview touches on the topics of trade tensions and the continued commitment of the CPI to sustainability goals. Dickson outlines some of the longterm effects he expects from the current pandemic, including changes to the way we work, an acceleration of technology and an overall increased speed to commerce.

Improving Plastics Recyclability — Brands and consumers are putting more emphasis on the recyclability of plastic products and manufacturers are committed to pursuing a circular economy. Alan Schrob is the consumer and industrial films group manager for NOVA Chemicals' polyethylene business. In this interview, he explains NOVA Chemicals' development of a resin that is used to make biaxially oriented polyethylene, which enables the manufacture of a multilayer film for food packaging, among other applications, that is recyclable. Schrob explains the significance of the development, which allows for good physical performance like heat resistance and stiffness for consumer packaging.

Neste's Sustainability Strategy —Theodore Rolfvandenbaumen, communications manager for Neste U.S., discusses Neste's goals to fight climate change and air pollution by producing advanced biofuels from renewable, sustainably sourced materials. The company's recent acquisition of Mahoney Environmental, which collects and recycles cooking oil, is an important step in its growth strategy. Rolfvandenbaumen explains how the company follows strict standards for their suppliers to ensure that their raw materials are sustainably and responsibly sourced.

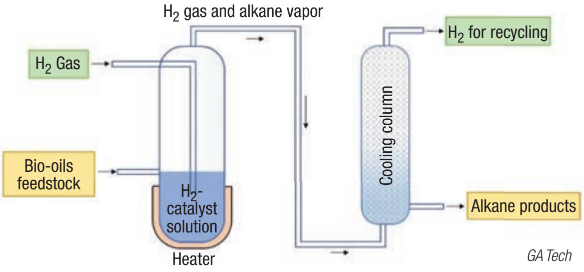
The Challenges of Turndown — In this video, Rajiv Narang, director of the Process Economics Program at IHS Markit, discusses challenges that facilities may face when running plant equipment at turndown, and what steps can be taken to avoid potential problems. This video interview is a follow-up to Narang's recent *Chemical Engineering* Online Exclusive article on the same topic. ■

Dorothy Lozowski, Editorial Director

A more efficient way to upgrade lignin bio-oils

Edited by:
Gerald Ondrey

Lignin bio-oil is a common waste stream formed during the production of cellulose and ethanol from biomass. Due to its high oxygen and low hydrogen content, lignin bio-oil must be upgraded via hydrogenation and deoxygenation before it can be used as a fuel. Furthermore, because of the very low hydrogen solubility in water and high activation energy of deoxygenation, lignin bio-oil upgrading typically requires processing at very high temperatures and hydrogen pressures.



GA Tech

Now, a team of scientists from Georgia Institute of Technology (Atlanta, Ga.; www.gatech.edu), led by professor Yulin Deng, has studied a solution-based, dual-catalyst system for combined hydrogenation and deoxygenation of lignin bio-oil that operates at ambient conditions (diagram). They found that polyoxometalate acid (SiW_{12}) can react with H_2, transfer H^+ to water, and release hydrogen as an active species inside the water in the presence of a platinum-based catalyst.

The team also observed that SiW_{12} can significantly reduce the activation energy of deoxygenation. As a result, SiW_{12} can act as both a hydrogen-transfer agent and a deoxygenation catalyst, which overcomes issues associated with hydrogen's low solubility in water at low pressures and the high activation energy of deoxygenation.

So far, the technology has been demonstrated in a laboratory-scale batch reactor. According to Deng, the process is versatile enough to produce many products beyond fuels, including benzene, cyclohexane, toluene, cyclohexanol and many others. "The key parameters to control the product selectivity include the type of catalyst, reaction time and temperature. Using different catalysts, the same lignin monomer may be converted to different final products," adds Deng. "We have only tested platinum and palladium so far, and we found the ratio of the final products shifts, which means the product selectivity can be adjusted by using different catalysts. This is one of our future research topics." The team is also looking at how lignin monomers can be partially hydrogenated or hydrodeoxygenated in the early stages of the reaction, and how the reaction progression over time can be controlled to yield different final products.

Increasing energy density in capacitors

Capacitors are attractive in large-scale energy-storage applications, such as electric vehicles or grid storage, because of their ability to rapidly charge and discharge, but their energy densities have been too small to allow their use in such applications. Researchers at Lawrence Berkeley National Laboratory (Berkeley, Calif.; www.lbl.gov) have developed a technique to boost the energy density of a "relaxor ferroelectric," a ceramic material commonly used as a capacitor in applications like ultrasonics, pressure sensors and voltage generators.

When a relaxor ferroelectric material is subjected to an electric field, a charge builds up, but the material will fail in the presence of strong electric fields. When discharging, the amount of energy available for use depends on the degree of electron polarization (orientation) in the ceramic. So the Berkeley team needed to find a way to render the material capable of withstanding high voltages while still retaining the electron polarization.

To do this, they bombarded a thin film of the relaxor ferroelectric material (specifically, niobite lead titanate) with high-energy helium ions, which introduced isolated point defects into the atomic structure of the film. The material with the targeted defects had more than twice the energy storage density than previously reported values, the researchers found.

Studies on the material revealed that the induced defects reduced the charge leakage, but also shifted the material's polarization-electric-field relationship, which means that it takes a higher voltage to reach the maximum electron polarization. The results suggest that ion bombardment can help to overcome the trade-off between being a highly polarizable material and being easily breakable, the researchers say.

ETHYLENE DICHLORIDE

Recently, Chemetry (Moss Landing, Calif.; www.chemetrycorp.com) and Braskem (Sao Paulo, Brazil; www.braskem.com) announced their intent to construct and operate a demonstration plant using Chemetry's eShuttle technology for the production of ethylene dichloride (EDC) in Brazil. The initial focus of this agreement will be the construction of a demonstration unit to be installed at Braskem's Chlor-alkali Maceió site, Alagoas State, Brazil. Chemetry's eShuttle technology eliminates chlorine generation from the traditional chlor-alkali process. It replaces the chlor-alkali and direct-chlorination processes with a single, integrated process that uses a circulating stream of aqueous copper chloride to transfer chloride ions from NaCl to ethylene. Like the processes it replaces, the eShuttle technology uses the same feedstocks — NaCl brine, water and ethylene — to produce the same products — EDC, caustic and H_2 — but at much lower energy and operating cost and without Cl_2 gas generation.

Li EXTRACTION

Energy Exploration Technologies (EnergyX; Newark, Calif.; www.energyx.com) recently announced a development partnership with Australian mining company Orocobre Ltd. (Brisbane; www.orocobre.com) on technology to extract lithium ions from salt brines. EnergyX's technology uses metal-organic frameworks (MOFs) embedded inside nanoscale channels in a polymer membrane to selectively separate lithium ions from salt brines. The method is envisioned as a more environmentally friendly lithium-harvesting alternative to conventional methods, such as mining lithium-containing ores and evaporating brine ponds under the sun. EnergyX anticipates full commercialization of the direct lithium-extraction technology in 2022.

SUPER-AUSTENITIC ALLOY

In late August, Sandvik Materials Technology, a part of the Sand-

(Continues on p. 6)

vik Group (Sandviken, Sweden; www.materials.sandvik/en) launched Sanicro 35, a unique grade that bridges the performance gap between stainless steels and higher-cost nickel alloys. Sanicro 35, the latest addition to Sandvik's growing Sanicro portfolio of nickel alloys and austenitic stainless steels, offers "exceptional high performance, strength and corrosion-resistance at a wide range of temperatures," says the company.

"Sanicro 35 is a unique, high-performance alternative to existing duplex and austenitic stainless-steel grades and more expensive nickel alloys. It offers a cost-efficient choice for minimizing risk and extending production lifecycles when battling corrosion in demanding environments," says business development manager Martin Holmquist.

Designed for extremely corrosive environments and seawater applications, the new alloy is said to be ideal for heat exchangers and hydraulic and instrumentation tubing. It features high mechanical-yield strength, superior corrosion resistance and excellent structural stability.

SUPERELASTIC ALLOY

Researchers from Tohoku University's Graduate School of Engineering (Sendai, Japan; www.eng.tohoka.ac.jp) have discovered a novel iron-based superelastic alloy (SEA) capable of withstanding extreme temperatures — both high and low. SEAs are found in a wide variety of commercial applications because of their superelasticity, which allows them to regain their original shape. Superelasticity occurs when the metal undergoes deformation at the point known as critical stress.

Generally, SEAs have a positive temperature dependence; the critical stress increases as the temperature rises. Conventional metal-based SEAs, such as Ti-Ni, cannot be used at temperatures lower than –20°C or higher than 80°C and are costly to make. This limits their application to the form of thin wires or tubes.

Associate professor Toshihiro Omori and his team developed an iron-based SEA system, known as Fe-Mn-Al-Cr-Ni. This cost-effective SEA can also operate at a much wider temperature range of –273 to over 120°C. Another significant advantage of the new SEA is its controllable temperature dependence. Increasing the amount of chromium enables the researchers to change the temperature dependence from a positive to a negative. Balancing the Cr content resulted in zero temperature dependence with the critical

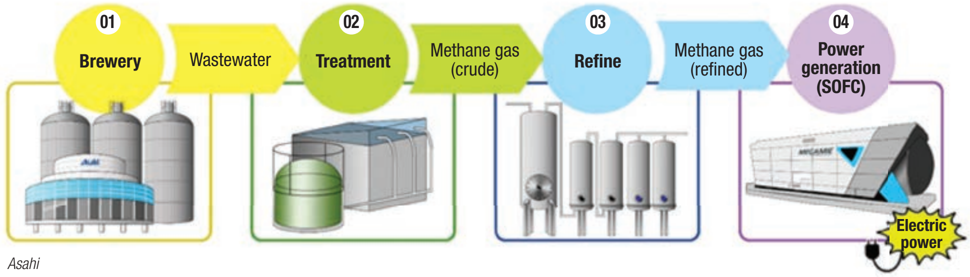
(Continues on p. 8)

Biogas from brewery wastewater makes power with a fuel cell

This month, a demonstration project to generate power from fuel cells running on biogas has begun at Asahi Breweries' Ibaraki Brewery. Coordinated by Asahi Quality & Innovations, Ltd., an independent research subsidiary of Asahi Group Holdings, Ltd. (Tokyo, Japan; www.asahigroup-holdings.com), the project is being conducted as part of the Japanese government's Low Carbon Technology Research, Development and Demonstration Program, with subsidies from the Ministry of the Environment.

In the project (diagram), biogas is first collected from the brewery's wastewater treatment plant and then refined into methane. The methane is then used as fuel for a 200-kW Megamie solid-oxide fuell cell (SOFC), from Mitsubishi Hitachi Power Systems, Ltd. (MHPS; Yokohama; www.power.mhi.com), to generate electric power. Once in operation, the facility will be capable of supplying around 1,600 MWh/yr of power — sufficient to power 350 ordinary households, with projected reductions in CO_2 emissions of around 1,000 metric tons per year.

With the goal of reducing CO_2 emissions, Asahi Group has been working to introduce power generation facilities utilizing high-energy conversion efficiency fuel cells to secure base electricity power to operate its factories. In June 2018, the company had developed a process to refine the biogas generated during the treatment of brewery wastewater to a high purity, allowing it to be utilized as the power source with carbon-neutral fuel cells. The company conducted tests to generate power with small SOFCs using this refined biogas, and in May 2019 successfully generated power continuously for 10,000 hours. Asahi Group has now begun the final stage of testing for practical application with the installation in the Ibaraki Brewery of a MHPS Megamie SOFC system, which was first commercialized in 2017 to run on ordinary town gas. This project is the first application using biogas derived from brewery wastewater as fuel.



Asahi

Fruit peels help recover metals from e-waste

Scientists from Nanyang Technological University (NTU; Singapore; www.ntu.edu.sg), led by professor Madhavi Srinivasan, have developed a method of using orange peel waste to extract precious metals from spent lithium-ion batteries and to make batteries from those recovered metals, creating minimal waste in the process.

"Currently, industrial e-waste recycling processes are energy-intensive and emit harmful pollutants and liquid waste, pointing to a need for eco-friendly methods as the amount of e-waste grows," says Srinivasan. "Our team has demonstrated that this is possible with biodegradable substances."

A method that has been increasingly explored involves hydrometallurgy, using water as a solvent for extraction. In this process spent batteries are shredded and crushed to form a material called "black mass." Metals are then extracted from the black mass by dissolving it in a mix of acids and other chemicals, such as hydrogen peroxide under heat. However, using such strong chemicals on an industrial scale would generate a large amount of pollutants.

The NTU team found that the combination of orange peel that has been oven-dried and ground into powder, and citric acid, can achieve the same goal. The team found that its approach extracted about 90% of cobalt, lithium, nickel and manganese from spent lithium-ion batteries — an efficiency comparable to the method using hydrogen peroxide.

The key lies in the cellulose in orange peel. The cellulose is converted into sugars under heat during the extraction process. These sugars enhance the recovery of metals from battery waste. Antioxidants found in orange peel, such as flavonoids and phenolic acids may also have contributed to this enhancement. Solid residues generated from this process were found to be non-toxic.

stress remaining almost constant at various temperatures.

"The discovery possesses widespread application for outer-space exploration given the large temperature fluctuations that occur," says Omori. Also, "it can potentially be used in tension braces in buildings or column elements in bridges — providing greater resistance to earthquakes," adds Omori.

A NEW NYLON

Toray Industries, Inc. (Tokyo, Japan; www.toray.com) has developed a new, more-sustainable nylon trade-named Ecodear. Ecodear Nylon is 60% bio-based, developed with sebacic acid generated from castor beans. The resulting fiber, initially available in 10, 20- and 50-denier versions, can be spun in the same process as conventional nylon, and can be used to make bio-based versions of the company's brand technologies, such as Dermizax and Entrant. Toray plans to market the textile this fall, targeting the active outdoor sports and skiing markets, as well as leisure markets. Toray International America Inc. (New York, N.Y.) will provide the new textile in North America.

OXYGEN SCAVENGER

Equinor (Stavanger, Norway; www.equinor.com) has worked with Clariant Oil Services (Houston; www.clariant.com) to optimize the volume of the oxygen scavenger being used on the Norwegian offshore oil platform, the Johan Sverdrup. "As part of our optimization process, our team took the existing O_2 remover being used by the platform, Clariant's incumbent product — a liquid-grade, sulfite-based oxygen scavenger — and looked at how we could make it a more efficient product, formulating a catalyzed version," says Jarle Skjold, global corporate account manager at Clariant Oil Services.

In field trials, the teams were able to reduce the volume of the O_2 remover used. After replacing the incumbent product with the specially formulated Clariant replacement product, the installation was able to achieve significant cost savings of around $800,000/yr, as

(Continues on p. 9)

Graphene-POSS polymer additives enable lightweighting

MITO Material Solutions (Indianapolis, Ind.; www.mitomaterials.com) has developed a proprietary graphene-functionalization technique that produces unique strength-enhancing additives for a wide variety of polymers and composites. The additives significantly improve mechanical properties (including tensile strength, flexural modulus and others) of the plastics and composites, allowing manufacturers to replace metals in a range of applications requiring high strength and light weight.

The additives are a class of modifiable compounds that combine polyhedral oligomeric silsesquioxane (POSS) — a silicon-oxide molecule with organic functional groups that was previously developed by Hybrid Plastics (Hattiesburg, Miss.; www.hybridplastics.com) — with either graphene-oxide (GO), a two-dimensional hexagonal lattice of carbon with oxygen functionalization on the edges, or starch. The combined graphene-POSS additive, known as E-GO, is the company's first product and is now available for user testing. Other products are in development.

A major advantage of E-GO is its ability to mitigate dispersion-related problems, such as settling and agglomeration. The E-GO additive alleviates these shortfalls "by providing the proper interlayer spacing within the GO platelets, while providing the proper reactionary sites via our production processes," explains MITO co-founder and CEO Haley Keith.

To manufacture the additives, MITO has developed a robust, high-yield proprietary process that was recently scaled from the laboratory to a contract manufacturing facility. The micron-scale powder additives are then mixed into polymer resins, where they reactively disperse into nanoscale particles that increase strength properties. "Integrating the highly dispersable additives into a manufacturing process is very easy without disrupting existing polymer processes, and it only takes 0.1% by weight concentrations of the additives to realize a significant improvement in mechanical properties," says MITO chief engineer Kevin Keith, who founded the company with his wife, the CEO.

MITO additives enhance fiber-reinforced composites and thermoplastics from 30 to 135% beyond standard performance metrics, the co-founders say.

In late August, MITO announced $1 million in seed funding, led by two Chicago-based firms, Dipalo Ventures and Clean Energy Trust. The company is also supported by a Small Business Innovation Research (SBIR) grant from the National Science Foundation.

Single-atom thin platinum makes a sensitive chemical sensor

Boosting the sensitivity of solid-state gas sensors is often achieved by incorporating nanostructured materials as the sensing element. However, interfacial effects at nanoparticles, grains or contacts can lead to non-linear responses, high electrical resistance or electrical noise. A possible way to overcome such drawbacks, using a one-atom thin layer of platinum on silicon carbide, has been reported by a team of researchers, led by scientists at Chalmers University of Technology (Gothenburg, Sweden; www.chalmers.se), and recently published in *Advanced Material Interfaces*.

These electrically continuous Pt layers are prepared by physical vapor deposition on the "carbon zero layer" (buffer layer) of silicon carbide. The buffer layer is a graphene-like 2-D electrical insulating layer grown epitaxially on the silicon terminated face (0001) of 4H-SiC. This layer enables the 2-D growth of Pt, and also serves to detect the onset of electrical conductivity of the surface as the metal deposits. The 3–4-Å thin Pt layer is found to be "super sensitive to its chemical environment," explains Kyung Ho Kim, postdoctoral fellow at the Quantum Device Physics Laboratory at the Dept. of Microtechnology and Nanoscience at Chalmers, and lead author of the article. "Its electrical resistance changes significantly when it interacts with gases."

"Atomically thin platinum could be useful for ultra-sensitive and fast electrical detection of chemicals. We have studied the case of platinum in great detail, but other metals like palladium produce similar results," says associate professor Samuel Lara Avila.

The researchers used the sensitive chemical-to-electrical transduction capability of atomically thin Pt to detect toxic gases at the parts-per-billion level. They demonstrated this with the detection of benzene, a compound that is carcinogenic even at very small concentrations, and for which no low-cost detection apparatus exists. The 2D system opens up a route for resilient and high-sensitivity chemical detection and can be the path for designing new heterogeneous catalysts with superior activity and selectivity.

An electrochemical process treats wastewater from biofuels production

Researchers from the School of Chemical and Biomolecular Engineering at the Universiy of Sydney (Sydney, Australia; www.sydney.edu.au), led by Alejandro Montoya, have developed an electrochemical oxidation process to clear up wastewater, which is heavily contaminated with organic and inorganic species during a biofuel production process, using naturally abundant microalgae. The electrochemical oxidation process uses a boron-doped diamond anode to improve the quality of the aqueous-phase coproduct from the hydrothermal liquefaction (HTL-ACP) of microalgae *Chlorella sp*.

According to the researchers, the oxidation process produced an outstanding decrease of the chemical oxygen demand (COD) — ranging from 11 to 185 g/L with a median value of 65 g/L — including the decomposition of organic nitrogen and the discoloration of an original brown HTL-ACP. The nitrogen remains largely as ammonia/ammonium and nitrates. The deamination of nitrogenous organic compounds with subsequent accumulation of NH_3/NH_4^- in the HTL-ACP and the partial oxidation to N_2 take place more easily at lower current density, while the complete oxidation to NO_3^- is more pronounced at higher current densities.

The HTL-ACP contains between 25 and 50% of the carbon from the feedstock, as well as nitrogen, phosphorus, and a variety of ions. The total nitrogen ranges from 2.3 to 13.6 g/L with ammonia comprising 20 to 50% of total nitrogen content and the remaining appearing mainly as toxic *N*-heterocyclic organic compounds.

The researchers say the high variability of COD and total nitrogen are associated with the diverse combinations of HTL process conditions, such as biomass composition, feed slurry concentration, temperature, pressure and residence time. These conditions define the yield and quality of biocrude and HTL-ACP properties.

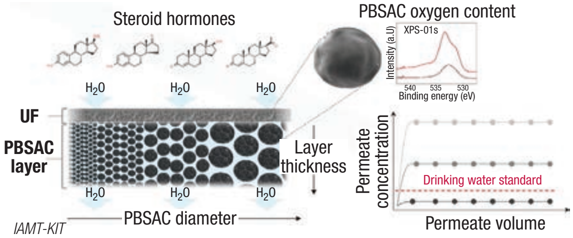
well as multiple sustainability improvements, including reduced chemical and energy usage, and production and shipping efficiencies, says Clariant.

The Johan Sverdrup is one of Norway's largest oilfields and will, at peak production, supply 25% of the Norwegian oil supply. Production started in October 2019 where Clariant was awarded the production chemical supply contract in 2017 and has been part of the project phase supporting Equinor in the development of this giant new oil field.

BIO-BASED PREPOLYMER

Lanxess AG (Cologne, Germany; www.lanxess.com) has recently developed a new range of methylen diphenyl diisocyanate (MDI) polyether prepolymers containing renewable, bio-based raw materials. Marketed under the brand name Adiprene Green, the products are suitable as replacement for existing fossil-based polyether prepolymers to manufacture highly durable polyurethane (PU) elastomers. Depending on the system, a reduction of CO_2 between 20 to 30% is possible compared to fossil-based prepolymers due to the use of polyether polyols based on starch. ❑

New process efficiently filters hormones from water



IAMT-KIT

Drinking water can be contaminated with micropollutants, including steroid hormones that are used as medical substances and contraceptives. Although their concentration in wastewater may be only a few nanograms per liter, this small amount can already damage human health and adversely affect the environment. Due to the low concentration and small size of the molecules, steroid hormones not only are difficult to detect, but also difficult to remove — conventional sewage-treatment technologies are not sufficient.

To handle this problem, professor Andrea Iris Schäfer, head of the Karlsruhe Institute of Technology's (KIT; Germany; www.kit.edu) Institute for Advanced Membrane Technology (IAMT) and her team have developed a process that combines ultrafiltration (UF) with activated carbon adsorption in a single filtration medium.

IAMT researchers have further developed and improved this process together with filter manufacturer Blücher GmbH (Erkrath, Germany; www.bluecher.com), while colleagues from KIT's Institute of Functional Interfaces, Institute for Applied Materials, and the Karlsruhe Nano Micro Facility characterized the material. The study was published in the October 15 issue of *Water Research*.

In the process (diagram), water is first pressed through a semipermeable membrane that eliminates larger impurities and microorganisms, Schäfer explains. "Then, water flows through the layer of carbon particles behind (the membrane), which bind the hormone molecules."

Scientists used modified carbon particles (polymer-based spherical activated carbon; PBSAC). The key was to determine the optimal diameter of the carbon particles. Using an activated carbon layer of 2-mm thickness, the researchers decreased the particle diameter from 640 to 80 µm and succeeded in eliminating 96% of the estradiol contained in the water. By increasing the oxygen concentration in the activated carbon, adsorption kinetics was further improved and a separation efficiency of estradiol of more than 99% was achieved. "The method allows for a high water flowrate at low pressure, is energy-efficient, and separates many molecules without producing any harmful byproducts," says Schäfer. "Our technology allows us to reach the reference value of one nanogram estradiol [the physiologically most effective estrogen] per liter drinking water proposed by the European Commission." ■

Business News

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- PETRONAS CHEMICAL
- REPSOL
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Plant Watch

Braskem begins commercial production at La Porte PP plant

September 11, 2020 — Braskem America (Philadelphia, Pa.; www.braskem.com) launched commercial production at its new polypropylene (PP) production line in La Porte, Tex., which has a production capacity of over 450,000 metric tons per year (m.t./yr) and has the capability to produce homopolymer, impact copolymer and random copolymers. Construction began in 2017, with the final phase of mechanical construction completed in June 2020.

Amyris scales up production of fermentation-based cannabinoid

September 10, 2020 — Amyris, Inc. (Emeryville, Calif.; www.amyris.com) has successfully scaled up production of the cannabinoid compound cannabigerol (CBG) using an industrial fermentation process. Amyris expects to deliver about 1 ton of high-purity CBG through fermentation, which is an alternative to the traditional production method of extraction from the *Cannabis sativa L.* plant.

Momentive to expand silicone production capacity for electronics applications

September 9, 2020 — Momentive Performance Materials Inc. (Waterford, N.Y.; www.momentive.com) is investing $15 million in expanded electronic materials production in its Waterford, N.Y., facility. This immediate investment will drive enhanced assets and silicone-production capabilities that will be operational in 2021.

LyondellBasell starts up molecular-recycling plant in Italy

September 8, 2020 — LyondellBasell Industries N.V. (Rotterdam, the Netherlands; www.lyondellbasell.com) started up a molecular-recycling facility in Ferrara, Italy. LyondellBasell's proprietary recycling technology aims to return post-consumer plastic waste to its molecular form for use as a feedstock for new plastic materials.

Chandra Asri starts up MTBE and B1 plants in Indonesia

September 8, 2020 — PT Chandra Asri Petrochemical Tbk (Jakarta, Indonesia; www.chandra-asri.com) has commenced operation of its new methyl *tert*-butyl ether (MTBE) and 1-butene (B1) plants. These facilities are the first of their kind in Indonesia. Construction on the plants began in 2018, with Toyo Engineering Corp. and PT Inti Karya Persada Tehnik (IKPT) providing services.

Air Liquide announces new investment serving Eastman Chemical in Texas

September 3, 2020 — Air Liquide S.A. (Paris, France; www.airlqiuide.com) announced a longterm supply agreement with Eastman Chemical Co. (Kingsport, Tenn.; www.eastman.com) to provide additional gaseous oxygen, nitrogen and synthesis gas supporting Eastman's production facilities in Longview, Tex. Air Liquide will invest more than $160 million to modernize existing assets and build a new air-separation unit and partial oxidation unit.

Bora LyondellBasell JV starts up polyolefins plant in China

September 1, 2020 — LyondellBasell and China's Liaoning Bora Enterprise Group started up their new joint-venture (JV) polyolefin complex in Liaoning, China. The 50-50 JV will operate under the name Bora LyondellBasell Petrochemical Co. Ltd. (BLYB). The BLYB facility includes a 1.1-million-m.t./yr flexible cracker and associated polyethylene production capacity of 800,000 m.t./yr, as well as 600,000 m.t./yr of polypropylene capacity.

Repsol to upgrade Tarragona plant to produce new impact-resistant polymers

August 28, 2020 — Repsol S.A.'s (Madrid, Spain; www.repsol.com) industrial complex in Tarragona, Spain will adapt one of its units to manufacture advanced polymers with high resistance to impact. The project has a budget of approximately €32 million. When operational in 2021, the plant will be the first of its kind in the Iberian Peninsula. In order to manufacture this new range of polymers, the company will install a second reactor at one of its PP production units in Tarragona.

Evonik to invest in Marl C4-production network

August 27, 2020 — Evonik Industries AG (Essen, Germany; www.evonik.com) is investing around €15 million in its C4-production network in Marl, Germany. Targeted debottlenecking measures will increase the local production capacity for isobutene derivatives, such as trimethylhexanal (TMH), *tert*-butyl alcohol (TBA) and diisobutylene (DiB), by more than 50% by December 2021. In addition, logistics will be further expanded in order to increase the flexibility of supply.

Petronas Chemical and LG Chem to build new NBL plant in Malaysia

August 24, 2020 — Petronas Chemicals Group Berhad (PCG; Kuala Lumpur, Malaysia; www.petronas.com/pcg) and LG Chem Ltd. (Seoul, South Korea; www.lgchem.com) agreed to build a nitrile butadiene latex (NBL) manufacturing plant at the Pengerang Integrated Complex (PIC) in Johor, Indonesia, to target the growing nitrile glove market. Construction of the plant will begin in 2021, while production is scheduled to start in 2023. When completed, the plant will have a production capacity of 200,000 m.t./yr of NBL.

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Mergers & Acquisitions

DuPont sells its trichlorosilane business

September 10, 2020 — DuPont (Wilmington, Del.; www.dupont.com) has divested its trichlorosilane (TCS) production business to Hemlock Semiconductor Operations (HSC). TCS is the primary raw material used in producing ultra-pure polysilicon supplies for the semiconductor and solar industries. DuPont's TCS business owns a production facility in Midland, Mich., which will enable HSC to control supply and substantially reduce costs.

KBR and JM join forces for new ammonia-methanol process

September 8, 2020 — KBR, Inc. (Houston. Tex.; www.kbr.com) and Johnson Matthey (JM; London, U.K.; www.matthey.com) have signed an agreement to license a new ammonia-methanol co-production process. The co-production process is based on technologies utilizing KBR's proprietary Purifier ammonia process and JM's methanol process, leveraging possible synergies between the two processes. The co-production of methanol and ammonia in a single plant offers the potential to reduce capital expenditures and operating expenses.

Ascend completes acquisition of Italian firms

September 3, 2020 — Ascend Performance Materials, LLC (Houston; www.ascendmaterials.com) completed its acquisition of Italian firms Poliblend and Esseti Plast. With this purchase, Ascend expands its portfolio into additional engineered plastics, recycled resins and masterbatches. The acquisition also includes Poliblend Deutschland, a distribution facility located in Germany.

AkzoNobel acquires Stahl Performance Powder Coatings

September 2, 2020 — AkzoNobel (Amsterdam, the Netherlands; www.akzonobel.com) has completed the acquisition of Stahl Performance Powder Coatings and its range of products for heat-sensitive substrates. The Stahl technology acquired by AkzoNobel is the only one of its kind in the powder coatings industry. It includes both ultraviolet and thermally curing powders, and will enable the company to penetrate the ultra-low cure domain.

Huntsman sells stake in Venator for $100 million

August 31, 2020 — Venator Materials plc (Wynyard, U.K.; www.venator.com) announced that funds advised by SK Capital Partners, L.P. have agreed to purchase approximately 42.5 million Venator shares, representing just under 40% of Venator's outstanding shares, from Huntsman Corp. (The Woodlands, Tex.; www.huntsman.com) for a purchase price of approximately $100 million. The transaction is expected to close near year-end.

Evonik acquires U.S.-based catalyst specialist Porocel

August 26, 2020 — Evonik is acquiring Porocel Group (Houston; www.porocel.com) for $210 million to accelerate the growth of its catalysts business. Porocel offers a technology for highly efficient rejuvenation of desulfurization catalysts, which are in increasing demand to produce low-sulfur fuel. Porocel has production facilities in the U.S., Canada, Luxembourg and Singapore. The transaction is expected to close by the end of 2020. ■

Mary Page Bailey

Gadgets for Today's CPI

New mobile devices, apps and augmented reality are supporting the digitalization revolution, as well as keeping business going during the pandemic

Anyone who has visited or toured a production plant of the chemical process industries (CPI) knows that mobile phones not only have to be turned off, but are often even forbidden to be carried inside the production site. That's because common mobile devices are safety hazards as potential ignition sources — even when turned off.

Nevertheless, with the advent of Industry 4.0 and the industrial internet of things (IIoT), smartphones, tablets and other hand-held devices are increasingly becoming a common sight within production plants. These "special" devices have been designed to be safe, as well as rugged, in order to be used in such industrial settings. And like the electronic gadgets widely used by consumers, new models, as well as the applications (apps) running on them, are regularly being introduced.

In addition, the use of augmented reality (AR) is becoming more important, especially for performing service work, while meeting new distancing restrictions due to the novel coronavirus. What follows is an overview of some products and services recently introduced.

Mobile devices

"Today, tasks and challenges for companies in the CPI are more complex than ever before," says Roolf Wessels, managing director at ECOM Instruments GmbH (Assamstadt, Germany; www.ecom-ex.com) — a brand of Pepperl+Fuchs SE (Mannheim, Germany; www.pepperl-fuchs.com). "That is why there is growing demand for digital and mobile hubs, which are embedded in a corporate IT [information technology] infrastructure and part of a holistic solution comprising hardware and applications for data use and increased effectiveness."

"Today, it is all about agile mobile workplaces — a new work model that requires access to all relevant information and the ability to access and share data while working from home, but above all, in production and on the factory floor," continues Wessels. "To meet this demand and support our customers, we are continuously developing our portfolio of end devices and peripherals, as well as digital products and services," he says.

ECOM's devices, which have been specially developed for rough industrial conditions in potentially hazardous areas of ATEX zones 1/21 and Div. 1, such as chemical plants, petroleum refineries or oil platforms, range from Android and Windows tablets to the company's own smartphone series.

Just last month, ECOM introduced Tab-Ex Pro (Figure 1). "With its 10.1-inch screen, the Android tablet is particularly suitable for applications that require a large display," says Wessels. "With the DeX feature, users can switch from field use to full desktop use in the office with a flick of their wrist. Despite its robustness and display size, the tablet is still light and handy."

ECOM offers a range of end devices complemented by universally applicable peripherals that create maximum user benefit. Devices such as the Smart-Ex Watch 01, the Cube 800 (the first portable and explosion-proof infrared and HD video camera for zone 1/21 and Div. 1), scanners or headsets, provide further user convenience, says Wessels.

Earlier this year, Juniper Systems, Inc. (Logan, Utah; www.junipersys.com) released the Mesa 3 Rugged Tablet. "The Mesa 3 running Android operating system is not only a great


ECOM Technologies

FIGURE 1. The Tab-Ex Pro is said to be the world's first 10-in. tablet for hazardous areas

Android tablet, but it is also one of the most rugged Android tablets in the world," says Jeff Delatore, Mesa product manager. "The Mesa 3 running Android joins the Mesa 3 running Windows 10 and offers customers a greater selection of devices to choose from."

The Mesa 3 running Android comes in with an IP68 rating and meets MIL-STD-810G test procedures. These ratings and testing mean the Mesa 3 running Android is waterproof, dustproof and shockproof.

Meanwhile, i.safe Mobile GmbH (Lauda-Koenigshofen, Germany; www.isafe-mobile.com) has more than 10 years of experience in the development of equipment for use in explosion-hazard areas. All i.safe Mobile products are certified for safe use in hazardous areas (including ATEX, IECEx, CSA, EAC) and are suitable for robust use in industry settings and outdoors.

In January, Softing Industrial Automation GmbH (Haar, Germany), together with i.safe Mobile and ProComSol Ltd. (Lakewood, Ohio), introduced a solution for setting the parameters and configuring HART field devices in Android applications, also in hazardous areas. The bundle is available from i.safe Mobile. "The mobiLink interface, in combination with our IS930.1 tablet and IS530.1 smartphone and ProComSol's DD-based apps is a powerful offering for our customers," says Martin Haaf, i.safe Mobile CEO.

AR for remote servicing

The augmented- and virtual-reality market is projected to grow 40% annually from 2017 through 2025, according to multiple research reports. Much of this spending will come from manufacturers around the globe using AR technology to help upskill their workforce for digitalized operations, according to Emerson Automation Solutions (Austin, Tex.; www.emerson.com).

"We also believe that the development of augmented reality applications for the industrial sector continues to advance," says ECOM's Wessels. "The first companies are already using well-functioning applications, while others are at the beginning of promising projects. Our Tab-Ex series, as well as our smartphones, have been designed to be perfectly suited for displaying and interacting with interactive, web-based and AR content quickly and seamlessly in hazardous areas," he says. "The need is there and will continue to grow. Our devices are prepared for it."

Meanwhile, Endress+Hauser AG (E+H; Reinach, Switzerland; www.endress.com) released its Visual Support service application in June, ahead of schedule during the coronavirus crisis. In the acute phase of the pandemic, users were able to take advantage of the remote audio-visual support free of charge.

The use of this technology for remote support enables audio-visual support for diagnosis and troubleshooting, commissioning and regular maintenance of field devices. With the help of live video transmission and screen casting, E+H's technical support team can work almost as if they were on site, helping customers in a reliable and flexible manner with their service tasks via remote access.

Also in June, Emerson introduced augmented reality (AR) technology to its Plantweb Optics asset-performance platform, delivering enhanced access to realtime diagnostics and analytics, as well as live remote assistance, to industrial plant workers responsible for maintaining and optimizing plant equipment. With AR technology integrated into Plantweb Optics, companies can improve productivity, collaboration and operational performance, without being limited by shortages of skilled workers or travel restrictions, says the company.

FIGURE 2. This recently launched AR service, which utilizes AR glasses, has already been demonstrated to save tens of thousands of dollars

Plantweb Optics leverages artificial intelligence, machine learning analytics and data contextualization to provide realtime visibility into plant reliability and operational performance. Unlike standalone AR solutions that require custom engineering, AR is integrated into Plantweb Optics, providing immediate access to a wealth of data and translating into easier, less costly implementation and a faster return on investment. For use by manufacturers in the life sciences, food-and-beverage, chemicals, metals, mining, water, pulp-and-paper and energy industries, Plantweb Optics is part of Emerson's Plantweb digital ecosystem of technologies, software and services.

AR for Plantweb Optics transforms the way field technicians accomplish complex tasks through enhanced situational awareness, live remote assistance and analytics delivered in context of the plant. As a field technician walks within an industrial plant with a mobile device, Plantweb Optics uses spatial computing technology to map assets and provide technicians with critical maintenance information relevant to their location. Plantweb Optics overlays realtime analytics, equipment health status and technical support documentation on their field of view, so technicians can safely resolve issues sooner.

In July, petrochemical giant Sibur (Moscow, Russia; www.sibur.ru) launched a universal AR service for remotely maintaining and repairing industrial equipment (Figure 2). Based on a unique IT platform of its own design, the service will replace face-to-face visits of service company specialists and experts with video consultations using AR glasses. This project was implemented in partnership with G-Core Labs (Luxembourg; www.gcorelabs.com), an international provider of cloud and edge solutions.

Sibur specialists first tested remote-servicing technology with the help of AR glasses in 2018 by using several solutions available on the market. The company's production facilities in the city of Tobolsk became the testing grounds.

"Our AR service is easy to use and includes two large key components: RealWear and Epson augmented reality glasses with pre-installed Android applications developed in collaboration with G-Core Labs and integrated with Sibur's own mobile-media platform," says Alexander Leus, head of Sibur Industry 4.0 practice. "This platform allows you to fully digitize the entire maintenance and repair process by organizing HD [high definition] broadcasts in WebRTC format and creating a full-fledged communication platform for effective on-site specialist interactions with a remote expert. Everything is voice-controlled, freeing the hands of the person to work with the equipment," says Leus.

"With the help of a virtual pointer displayed on the glasses' microdisplay, an employee of the equipment supplier company can direct the actions of the specialist, draw attention to certain elements, and indicate what to turn and where to monitor," explains Dmitry Samoshkin, vice president of Products at G-Core Labs.

"One session of operational communication through our AR platform helps save several tens of thousands of dollars," says Igor Klimov, member of the board, CEO of Sibur Tobolsk enterprises. "These savings result from the reduction in travel expenses, hourly billing instead of full-day billing for experts, and the timely resumption of work," he says. ■

Gerald Ondrey

A longer version of this story can be found online at www.chemengonline.com.

Focus on Seals and Gaskets

The Flexitallic Group

Garlock Pipeline Technologies

AGC Chemicals Americas

Mechanical joint-integrity training courses for the CPI

The Academy of Joint Integrity (www.academyofjointintegrity.com) has achieved approval from the Institution of Chemical Engineers (IChemE) for a suite of theory and practical training programs to support technicians and engineers in the chemical process industries (CPI). In addition to its established ECITB-accredited courses and CPD-accredited training courses covering the management of the integrity of flanged bolted connections, the Academy now provides five training modules approved by the IChemE. Designed specifically for the CPI, the training programs cover disciplines such as hand torque/hydraulically torque/hydraulic tensioning of flange joints and bolted connections. Training can be offered at the Academy's seven U.K. locations, as well as delivery on-site at customer facilities, by utilizing the unique Flange Assembly Demonstration Unit (FADU). The Academy, which is part of this company's global sealing industry specialists, supports industry with a comprehensive suite of joint integrity and sealing expertise. This includes a range of engineering services, such as technical consultations, engineering drawings, failure mode analysis and latest flange integrity calculations to EN1591. — *The Flexitallic Group, Inc., Houston*

www.flexitallic.com

A fully-coated isolation gasket that is also thin

Evolution iisolation gaskets feature easier installation, tight sealing, high-temperature operation, no permeation, hydrotesting isolation, fire-safety and chemical-resistance. With a thinner, 1/8-in. design, Evolution gaskets minimize the difficulties often encountered when attempting to install thicker isolating gaskets. The full-coating encapsulation allows the gasket to be hydrotested and left in the pipeline with the same isolation properties as before it was tested. Evolution's proprietary coating is extremely abrasion- and impact-resistant while providing chemical resistance to H_2S, steam, CO, CO_2 and other chemicals often found in oil-and-gas pipelines. This fully encapsulated coating also prevents the need for expensive exotic cores, as it eliminates contact to exposed metal. The Evolution gasket provides the highest tightness parameters for any product available in the market today, according to the manufacturer. It also provides the highest pressure rating of any isolating gasket available. Evolution gaskets can operate under high temperatures (rated to 500°F). — *Garlock Pipeline Technologies, Inc., Wheat Ridge, Colo.*

www.gptindustries.com

These fluoroelastomers enhance seal performance

This company offers AFLAS 100 series fluoroelastomers to enhance the performance and extend the life of pumps, seals and valves used in a variety of harsh processing applications. AFLAS fluoroelastomers — copolymers of tetrafluoroethylene and propylene with high molecular weights — are resistant to acids, bases, solvents, hydrocarbons, sour oil and amines, as well as to extreme temperature ranges and high-pressure environments. They are easily compounded by open mill and internal mixers. These compounds are then fabricated into finished parts and shapes using press molding, injection molding, extrusion (photo) and calendering processes. AFLAS 150P, 100S and 100H are FDA approved for food contact in the A-H temperature range. Classified by ASTM D 1418-01 as FEPM, AFLAS products do not deteriorate under prolonged exposure at 200°C. — *AGC Chemicals Americas Inc., Exton, Pa.*

www.agcchem.com

Labyrinth seal increases efficiency in severe service

The Arlon 4020 Labyrinth Seal (photo, p. 17) has a controlled thermal expansion over a wide range of temperatures, and has a uniquely engineered tooth profile that make it a cost-effective and long-lasting seal choice. Customer test results show up to a 1.5% gain in efficiency com-

pared to traditional seals, correlating with field tests and predictions from finite-element analysis (FEA). Non-contacting labyrinth seals reduce leakage in centrifugal applications. This is accomplished by restricting flow through a series of chambers formed between the rotating element while the teeth control the passage of the media. The improved performance is said to be due to the innovative combination of custom-engineered tooth designs and high-performance PEEK (polyether ether ketone) thermoplastic materials. The materials reduce friction and eliminate galling, which extends the seal's life and lowers maintenance costs. The erosion and corrosion resistance make the Arlon 4020 suitable for severe sealing applications. — *Greene Tweed, Landsdale, Pa.*
www.gtweed.com

Conductive sealing materials for dynamic applications

Launched last year, Turcon MC1 and Turcon MC2 materials are said to be the only polytetrafluoroethylene (PTFE) based electrically conductive materials suited for use in spring and elastomer-energized seals. "Engineered for dynamic applications, seals and bearings from the materials will provide reliable electric connection between moving parts," says Soeren Roepstorff, development manager at the company's manufacturing facility in Helsingør, Denmark, where the new compounds were developed. "Conductive elastomers are available, but these are primarily only for static applications, while the conductive, injection-moldable plastic materials that exist have low flexibility and are less suited for sealing purposes and for installation in closed grooves," he says. Electric charge transfer through the gap between two components can cause sparks or stray current in machinery and systems, for example in electric motors. This can result in hardware pitting and carbonization of lubricant or grease. Use of an electrically conductive seal or bearing grounds the system by creating a clear path between two components, avoiding corrosion issues. Turcon MC1 (photo, left) is a medium-filled material for dynamic applications requiring medium to high conductivity, while Turcon MC2 (photo, right) is a high-filled material for dynamic applications requiring high conductivity. — *Trelleborg Sealing Solutions Americas, Schaumburg, Ill.*
www.tss.trelleborg.com/en

This new sealing technology enhances pump performance

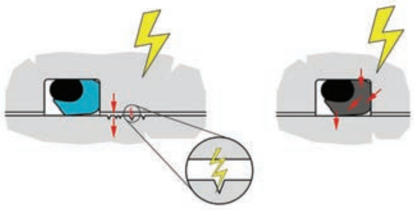
New developments of an innovative sealing technology have been added to the range of Viking Universal Seal Series of Internal Gear Pumps (photo). The result is a more cost-effective sealing option compared to traditional mechanical seals, while also reducing leakage rates compared to using pumps with packing. The new option is also designed for back pull-out, which helps to reduce downtime and simplify maintenance. Available from this company, the new O-Pro seal uses a series of O-rings to create a robust seal and lubrication chamber in a single-piece seal. This new feature can be fitted throughout the Viking Universal Seal Series pumps, which cover flows to 295 m^3/h, discharge pressures to 14 bars and liquid viscosities of 20–1,700 cSt at temperatures between –15 to 175°C. — *Michael Smith Engineers Ltd., Woking, U.K.*
michael-smith-engineers.co.uk

Chevron seals for flow-wrapping packaging

Flow-wrapping is one of the most cost-effective methods for packaging high-profile products. However, in medical device applications, it is more commonly applied to products where the product sterility of the outside of the product is not essential. This company is introducing chevron seals (photo) with peelable side seals, which dramatically improves ease of opening, making cost-effective flow-wrapping a feasible alternative for dimensional, larger, or bulky disposable products that require a strong, but easy-to-open seal. Chevron sealing is ideally suited to such products, as they can challenge seal integrity on all four package sides. This capability is particularly important given recently updated ISO 11607 guidelines that emphasize point-of-use aseptic presentation of terminally sterilized medical devices. — *Harpak-ULMA, Taunton, Mass.*
www.harpak-ulma.com ■

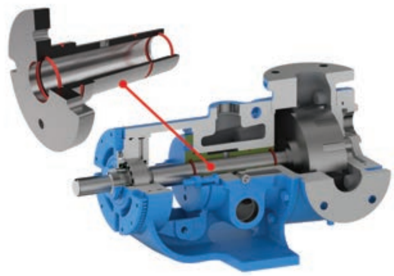
Gerald Ondrey

Greene Tweed



Trelleborg Sealing Solutions Americas

Michael Smith Engineers



Harpak-ULMA

Netzsch Pumpen & Systeme

SICK

Pentair

KNF Neuberger

Grinder product range extended to handle higher flowrates

The N.Mac twin-shaft grinder is now available in expanded sizes (photo) for flowrates up to 400 m³/h. The N.Mac is designed for breaking down a variety of different materials and is ideal for wastewater treatment, biogas and biomass plants, food processing and many other waste-handling and industrial applications. The N.Mac can be installed upstream of a pump (inline version) or above the feeding screw of a hopper pump (channel version) or in any effluent channel. The inline version of the N.Mac is available in three sizes and can handle a maximum flowrate of up to 350 m³/h. The channel version of this grinder is available in four sizes, designed for a maximum flowrate of up to 400 m³/h. For applications with even higher flowrates, several grinders can be run in parallel, additionally allowing parts of the system to be serviced during operation. Installation of several grinders in sequence allows a gradual reduction of the particle size. The N.Mac is equipped with flushed and lubricated mechanical seals for dry-running capability. — *Netzsch Pumpen & Systeme GmbH, Waldkraiburg, Germany*

www.netzsch.com

Measure oxygen in processes with this durable device

The Transic100LP oxygen transmitter (photo) uses tunable diode laser spectroscopy (TLDS) for repeatable and drift-free measurements, independent of process or sample gas flow, temperature and pressure. The device has no moving parts, and its optical components demonstrate durability, even when faced with liquid or dust incursions. The Transic100LP oxygen analyzer can be installed as a standalone in-situ analyzer, or as part of a close-coupled extractive measurement system. In-situ installations provide rapid response times and require no sample extraction or transport components for greater simplicity. Designed for in-process measurement, the optical probe is made of stainless steel with magnesium fluoride and quartz lenses for long-term durability. — *SICK Inc., Minneapolis, Minn.*

www.sick.com

More membrane surface area in a smaller footprint

The newest addition to this company's X-Flow line of membrane elements, the X-Flow XF75 ultrafiltration (UF) element (photo), can be implemented into both new and existing water-treatment projects. Although the outer dimensions are the same as those of existing X-Flow membrane elements with membrane areas of 55 and 64 m², this company has redesigned the internal workings and used modified materials to create extra membrane surface area. This latest update provides key advantages in terms of surface area in relation to element size. By maintaining the existing element outer dimensions and increasing the total surface area to 75 m², users can take advantage of more membrane surface area per unit of weight or volume than the average of similar UF technologies available today, says the company. — *Pentair plc, London, U.K.*

www.xflow.pentair.com

A new range of pumps for laboratory use

This company has introduced three new models to its Laboport series of laboratory pumps — the N 96, N 820 G and N 840 G (photo). These new diaphragm pumps expand upon the Laboport pump design with oil-free, non-contaminating, chemically resistant construction, as well as speed-controlled d.c. motors for greater versatility. N 820 G and N 840 G models include an integrated gas-ballast valve to facilitate short process times, even for high-boiling solvents. The smooth, rounded surfaces of all three pumps enable thorough cleaning. Compared to similar pumps, these new models are said to offer a 10–20% footprint reduction to and a 5–30% weight reduction for improved portability. The two larger pumps are expandable into custom vacuum systems by connecting an optional separator or condenser module. Maximum flowrates for the new series range from 7–34 L/min. Applications include rotary evaporation, degassing, filtration, fluid aspiration, gel drying, centrifugal concentration, vacuum ovens and more. — *KNF Neuberger, Inc., Trenton, N.J.*

www.knfusa.com

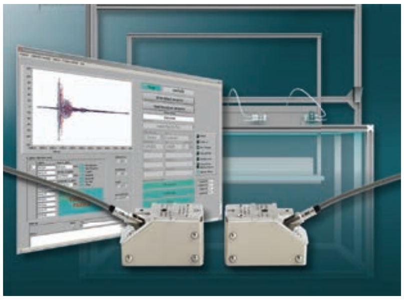
A new way to calibrate ultrasonic flowmeters

AperCal is a new calibration rig for this company's clamp-on ultrasonic flowmeters (photo). This new offering enables flowmeter users to conduct autonomous calibrations at their own sites. Typically, calibration consists of a comparison of the device under test with a reference instrument on a wet-flow calibration rig. However, the flow profile in every flow rig is influenced by pipe characteristics and installation conditions, leading to uncertainty. The patented, traceable aperture-calibration method eliminates uncertainties by defining the calibration process on the basics of clamp-on ultrasonic flow measurement according to the transit-time principle. AperCal produces the same effect, without flow, through defined displacement of the transducers. This reduces the calibration procedure to the measurement of length and time, both of which can be performed with high levels of precision. — *Flexim GmbH, Berlin, Germany*
www.flexim.de

High-performance footwear provides layers of protection

The Philadelphia Wellington heavy-duty workboot (photo) is built to withstand tough work environments, while also keeping feet comfortable. The Philadelphia Wellington features a full-grain, waterproof leather to help resist the damaging effects of many chemicals, including oleic acid, urea, sodium chloride, ammonium hydroxide and more. The boots are designed with left and right asymmetrical, non-metallic carbon-fiber toes, which are said to be 15% lighter than steel. The outer sole is oil- and slip-resistant, and it also heat-resistant up to 300°C (572°F). Furthermore, electrical-hazard- or electric-shock-resistant footwear provides a secondary source of protection in case the user accidentally comes into contact with live electrical circuits. The boots are also equipped with a polyurethane midsole and are lined with a moisture-wicking mesh textile. — *Keen Utility, Portland, Ore*.
www.keenutility.com ■

Mary Page Bailey and Gerald Ondrey



Flexim

Keen Utility

Facts At Your Fingertips

Hopper Outlet Geometry and Arching

Department Editor: Scott Jenkins

When transferring stored bulk-solids materials from hoppers, bins and silos, flow stoppage can occur because of bridging or arching at the vessel outlet. Hopper outlets must be large enough to prevent cohesive arches or stable ratholes from developing. Determining the size and shape of the hopper outlet is critical to ensuring that the bulk material flows. This column provides information on the interplay between bulk material properties and vessel geometry and how those relate to outlet size and shape.

Arch and rathole formation

Bulk solids can experience a range of conditions within a bin, silo or storage hopper. Consolidation pressures range from zero at the surface, to relatively large values at increasing depth within the container. If a solid gains cohesive strength because of the pressures applied to it, an arch or rathole could form. An arch (also called a bridge or dome) is a stable obstruction that forms over the point of narrowest cross-section of the storage vessel (usually the discharge outlet). The arch supports the rest of the bin contents, preventing discharge (Figure 1, left). A rathole is a stable pipe or vertical cavity that empties out over the outlet. Material is left stranded in stagnant zones that usually remain in place until an external force is applied to dislodge them.

Flow functions

Cohesive strength can be measured as a function of the applied consolidation pressure. By conducting the test over a range of consolidation states, the relationship between consolidation pressure and the cohesive strength of the bulk material can be established, following a procedure established and described by Jenike [*1*]. In a laboratory, a sample of the material is placed in a direct shear tester and both compressive and shear loads are applied to simulate flow conditions in a container. Once the sample has been consolidated, its strength is measured by shearing it to failure. By repeating this procedure under different conditions, the resulting value of strength versus consolidating pressure (called a flow function) can be developed. The material's flow function is then used to calculate minimum outlet dimensions.

Once a material's flow function has been determined, the minimum outlet width or diameter that will prevent cohesive arching can be calculated using the hopper's flow factor. The flow factor is a function of the powder's effective angle of internal friction, the hopper angle and the wall friction angle. Typical values of the flow factor range between 1.1 and 1.7. For more on calculating flow functions and flow factors, see Refs. 2 and 3.

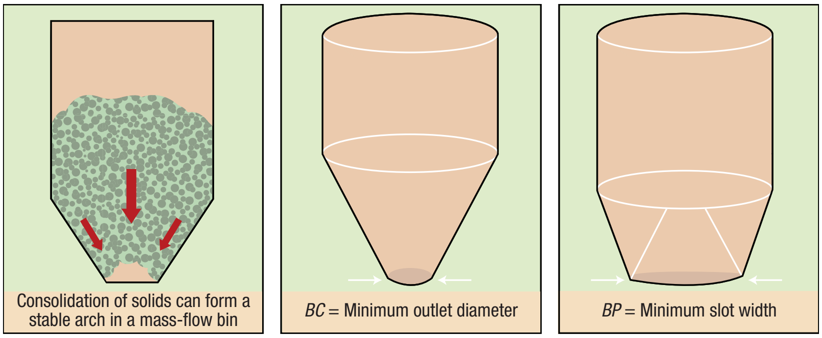


FIGURE 1. The size of the discharge outlet is a critical element in preventing the formation of an arch in a mass-flow bin

Mass- versus funnel-flow bins

Two types of bin flow patterns are possible. A mass-flow bin has a relatively long, tapered discharge section. In mass flow, all of the material is in motion during discharge, so no stagnant regions form. Conversely, a funnel-flow bin has a relatively short converging section. While storage capacity for a given height is greater in a funnel-flow bin, this geometry allows material in the center to move, while material at the walls is stationary. The resultant stagnant regions may interrupt flow.

Compared with a mass-flow bin, there are several potential advantages to using a funnel-flow bin. The relatively shallow hopper requires less headroom for a given storage capacity, and since there is minimal flow along the walls, the likelihood of abrasion and particle attrition is minimized. However, In general, only free-flowing solid materials with large (≥1/4 in.) particle sizes and minimal tendency to degrade (via oxidation, caking and so on) will flow reliably in funnel-flow bins.

Preventing arching

For a mass-flow bin with a circular outlet, the minimum outlet diameter needed to prevent arching is expressed as *BC* (Figure 1, center). Consider a material whose critical outlet dimension, *BC*, is 12 in. If this material is placed in a mass-flow bin with an outlet diameter of 6 or 8 in., a stable arch will form. Conversely, if the outlet size is 12 or 14 in., a stable arch cannot form, so the material will flow.

To prevent an arch from forming in a funnel-flow bin, the minimum width of a slotted outlet must be determined. The critical rathole diameter, *DF*, must also be determined. Ratholing is likely when the diameter of the flow channel (set by the size of the outlet) is smaller than *DF*.

Planar versus conical flow

The stress needed to deform a given solid also depends on the form of flow channel. In general, a wedge-shaped configuration with an elongated outlet is a more forgiving geometry that can handle a wider range of conditions for a given material without flow stoppages. The minimum outlet width required to prevent an arch from forming in a wedge-shaped, mass-flow hopper is expressed as *BP* (Figure 1, right). For a given material, this value is usually about half that of *BC*. ■

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Sodium Chlorate Production

By Intratec Solutions

Sodium chlorate ($NaClO_3$; also known as chlorate of soda) is an odorless inorganic salt with colorless crystals and a cooling/saline taste. The compound is soluble in water and most organic solvents. The main uses of sodium chlorate derive from its oxidizing characteristics, and its main application is as a bleaching agent in a variety of processes. Because of its high oxidizing power, sodium chlorate is generally not found naturally. Its first uses date to the beginning of the 20th century, however, its industrial production only began at the end of the 1960s.

The commercial-scale synthesis of sodium chlorate is mainly based on the electrolysis of a hot sodium chloride solution — similar to the widely used chlor-alkali processes. The main difference lies in the fact that there is no need to prevent the reaction between chlorine and hydroxide ions. The on-purpose synthesis of sodium chlorate through chemical reactions is not commonly employed on industrial scale.

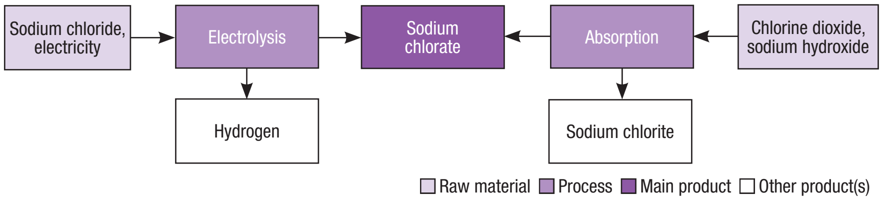

FIGURE 2. Brine electrolysis is the primary production pathway for sodium chlorate, but others exist

The process

The present analysis discusses an industrial process for sodium chlorate production. The process comprises two major sections: (1) electrolysis and (2) sodium chlorate recovery (Figure 1).

Electrolysis. In a salt dissolver, a brine solution is prepared from sodium chloride raw material and process water. After purification of the NaCl solution, hydrochloric acid and sodium dichromate are added (to increase cell efficiency and to protect electrodes from corrosion, respectively). The purified, acidified solution is then electrolyzed. At the cathodes, hydrogen gas is generated and released along with impregnated chlorine. The released gas is collected in a column that prevents chlorine emissions through caustic scrubbing. At the anodes, chlorine atoms generated from the electrolysis combine with water and free ions to form hypochlorous acid and sodium hypochlorite. Hypochlorous acid and sodium hypochlorite then react to form sodium chlorate. Reaction tanks downstream from the electrolytic cells provide a longer residence time for the chemical reaction between hypochlorous acid and sodium hypochlorite to take place. The liquor from the electrochemical cell is finally transferred to the crystallizer in the sodium chlorate recovery section.

Sodium chlorate recovery. Prior to crystallization, residual hypochlorites are eliminated through heating and addition of chemicals. The cells' liquor, virtually free of hypochlorites, is heated, subjected to vacuum evaporation and finally crystallized under vacuum. The sodium chlorate crystals are recovered by centrifugation, washed and fed to a dryer. Dry sodium chlorate is conveyed to silos prior to being packed into bulk bags.

Production pathways

Industrial-scale production of sodium chlorate is primarily based on brine electrolysis. Figure 2 presents different pathways for the production of sodium chlorate.

Economic performance

The total operating cost (raw materials, utilities, fixed costs and depreciation costs) estimated to produce sodium chlorate was about $440 per ton of sodium chlorate in the fourth quarter of 2016. The analysis was based on a plant constructed in the U.S. with the capacity to produce 80,000 metric tons per year of sodium chlorate.

This column is based on "Sodium Chlorate Production – Cost Analysis," a report published by Intratec. It can be found at: www.intratec.us/analysis/sodium-chlorate-production-cost. ■

Edited by Scott Jenkins

Editor's note: The content for this column is supplied by Intratec Solutions LLC (Houston; www.intratec.us) and edited by *Chemical Engineering*. The analyses and models presented are prepared on the basis of publicly available and non-confidential information. The content represents the opinions of Intratec only. More information about the methodology for preparing analysis can be found, along with terms of use, at www.intratec.us/che.

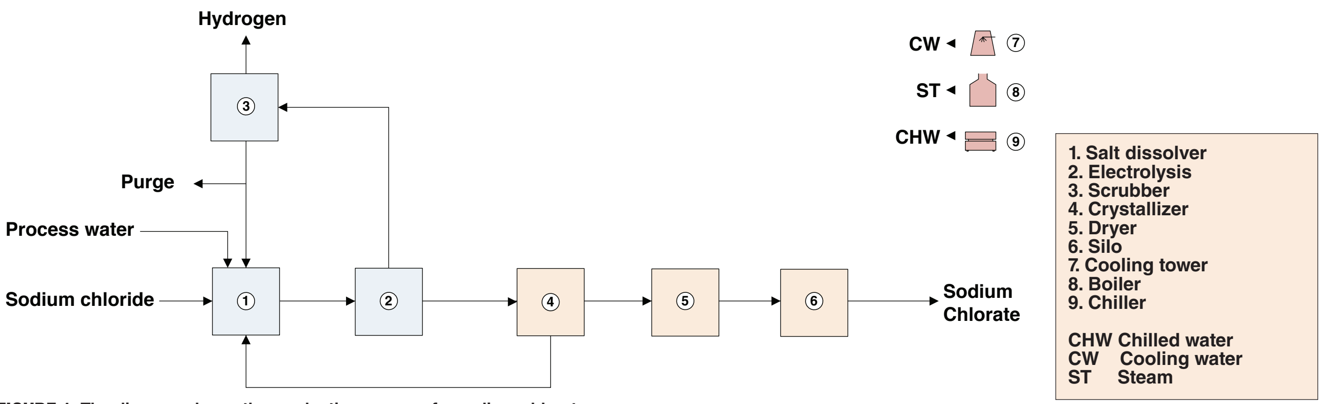

FIGURE 1. The diagram shows the production process for sodium chlorate

Leak Prevention in Small-Bore Piping and Tubing

Part 1

Improved understanding of the causes of piping leaks can reduce the frequency of leaks and lead to significantly better performance over time

Richard Palluzi
Richard P Palluzi LLC

IN BRIEF

Leakage in pipes is an ongoing problem in research and development facilities across many sectors of the chemical process industries (CPI), such as petrochemicals, pharmaceuticals, food and beverage and others. Leakage can negatively affect operations in pilot plants and laboratory units, and can affect a wide range of laboratory equipment, analytical instruments and testing equipment. Leaks are costly and time-consuming to find, and often are even more expensive to fix. Leaks result in poor-quality data or invalid results, which can require needless rework. Because leaks create unnecessary downtime and program delays, they drain stretched research resources.

Leakage is often ignored or accepted as a "necessary evil." It is common for scientists and engineers to talk about getting a system "leak tight" as if it is a one-time activity. Yet every system, no matter how well designed or well maintained, is almost certain to leak somewhere at some time. Therefore, leak testing needs to be a routine activity, not a one-time task. Simultaneously, research personnel commonly think of leaks as unfortunate, but inevitable occurrences, like adverse weather conditions — "unfortunate, but what can one do?" As a result of that mindset, few efforts are made to prevent or minimize the frequency of leaks.

Significantly better performance can be achieved over time by (1) understanding the common causes of leaks and (2) taking proactive steps to reduce their frequency. This article focuses on tubing and small-bore piping, which are more common in research and development.

Common causes of leakage

The following items constitute major causes of leakage in piping systems.

Improper assembly. Pipe threads are often under-tightened (Figure 1). Undersized wrenches are often used because they are handy or to get more clearance, but this results in the need to exert more force in connecting pipes, which is often not supplied. If upstream and downstream fittings are not properly held, they may slip before the necessary turns have been completed. In order to achieve the desired alignment, fittings are sometimes not tightened all the way. In order to get fittings to match up, they are often tightened insufficiently or forced into place. The former results in a connection that is too loose; the latter produces needless stresses, eventually promoting leaks.

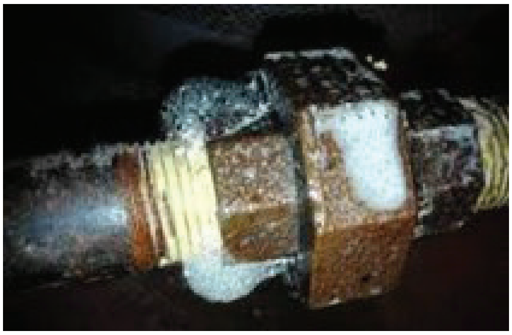

FIGURE 1. This photo shows a leaking pipe union, probably resulting from being under tightened or forced together during assembly

Poorly applied pipe sealant. Pipe sealant is often seen as an area to reduce costs, so inexpensive (and lower-quality) sealants may be used, or sealant material may be applied too lightly. Also, to save time, sealant may be applied unevenly. Tapes are allowed to bunch up due to poor assembly.

Badly threaded pipe fittings. Dies for threading pipes are often used well past their lifetimes, resulting in rounded threads that are difficult to seal and are prone to leakage (Figure 2). When standard dies are used to thread high-alloy pipe, they wear out quickly, usually well before anyone realizes there is a problem. Dies are sometimes not started carefully enough, resulting in threads that are not true and are more prone to leaks. Also, pipe threads can be cut too short or too long to make something fit an exact dimension.

Compression fittings are not tightened properly. Pipe fittings are often tightened by "feel" instead of by the number of turns. Worse, many are deliberately under-tight-

FIGURE 2. Badly rounded threads like those shown here are almost certain to leak

ened for longevity. Compression fittings that are routinely removed and replaced will, over time and dozens if not hundreds of cycles, eventually start to leak and need to be replaced. The more the fitting is tightened, the shorter the time until this can happen. Most manufacturers recommend 1¼ turns as a good compromise between longevity and integrity. However, good-quality compression fittings will often seal with fewer turns. So some personnel under-tighten compression fittings routinely to extend their life. But this results in a much greater chance of leakage, as the safety factor inherent in the manufacturer's recommendations is no longer present.

Tubing inserted improperly. If tubing is not inserted all the way into the fitting and fails to bottom out, this will result in a poor seal.

Debris and scratches. Fitting sealing surfaces and tubing outside surfaces are not generally treated carefully enough. Dirt, grit or foreign materials are often present, albeit in small amounts, but enough to cause gaps or scratches and promote leakage. Poor work practices prevent the fittings or the tubing from staying clean enough. Tubing is often badly scratched from poor handling practices, being dragged along floors, dirt, or other surfaces that produce small scratches that make it more difficult for the system to seal properly. All could be prevented by proper handling techniques.

FIGURE 3. The tubing shown in this photo was probably poorly aligned and felt like it was properly inserted to bottom out in the fitting. It leaked immediately upon startup and the entire piece had to be replaced

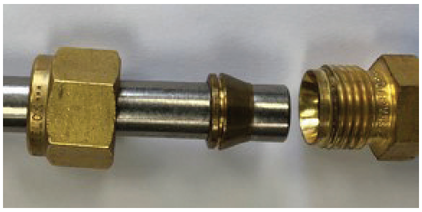

FIGURE 4. The softer copper ferrule shown in the photo will never seal properly on the harder stainless-steel tubing

Misalignment. Ferrules are left out, damaged, or so badly misaligned that sealing is compromised. Some tubing is not aligned properly (Figure 3). Either it is placed in at an angle or forced into the fitting in such a way that the resulting forces are working against the fitting itself, promoting leakage.

Tubing hardness. For compression fittings to work properly, the ferrules must be harder than the tubing, so they can bite into it (compress) and make a good seal (Figure 4). Thus, every quality manufacturer has a maximum recommended tubing hardness. Sadly, most tubing is bought from local suppliers with no reference to this property. This often results in tubing that is too hard for a good seal and numerous unnecessary leaks.

Heating and cooling

Routine temperature changes always create more leaks. Whether these are heating or cooling is immaterial. Large (>150°C) or rapid (>25°C/min) temperature swings can cause leakage in as little as one cycle. The author has seen fittings that started out leak-free and properly tightened become less than hand tight at the end of a heating or cooling cycle.

Ambient temperature swings, often routinely ignored, are a significant continuing problem. While slower and of less magnitude, ambient temperature swings happen with a much higher frequency (every day). The frequency more than compensates for the smaller magnitude and greatly promotes leakage. Common problem areas include pipes that are outdoors, in non-air-conditioned process bays, and facilities with significant off-hours temperature changes. Sterilization and cleaning-in-place are often overlooked as a source of the same issue.

Stress and torque

Pipe fittings that are subject to higher stresses and torque tend to leak more easily because these forces work against the sealing surfaces over time. Work on adjacent fittings or components can cause two leaks for each component touched (one on each side). Hold backs, or a wrench or pliers designed to prevent the body of the fitting from moving, are difficult to always coordinate properly. Often, users respond to the turning motion after the stationary fitting starts to move, so it has already been loosened. Other problem areas include equipment, components and pipe sections that are frequently removed. These will leak not only at the disconnect points, but also often at nearby connections. Turning a poorly supported valve increases the potential for the torque to loosen the fitting and cause a leak. Vibrations, bumps and similar shocks from equipment and operations all can contribute to leakage.

Clearance issues

Pipe threads, unions and compression fittings require clearance when connecting and disconnecting to allow components to be removed. It is often difficult to provide sufficient clearance, leading to problems including improper tightening, bent tubing or sprung piping (piping that has been forced together and has significant residual stresses trying

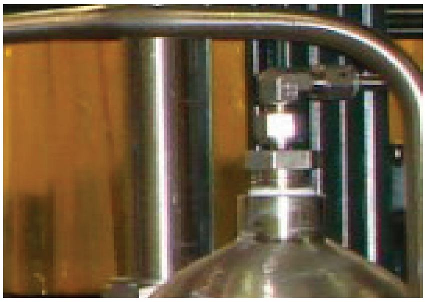

FIGURE 5. Buying the right fitting would reduce the potential leak points by two, by eliminating the pipe bushing

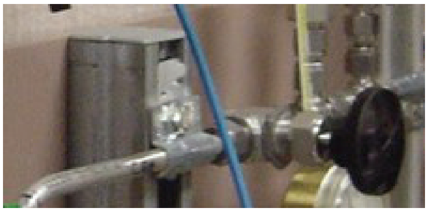

FIGURE 6. A second support downstream of the valve is necessary to minimize the force from turning the valve

to pull it apart). This is often a problem when piping or tubing is deliberately cut short to generate the clearance. In this case, it will tend to spring apart when loosened, allowing for easier removal, but leading to a much higher likelihood of leakage. Flanges and sanitary fittings are commonly pulled apart to make gasket access easier, resulting in stress on nearby fittings. This often results in bending nearby components and increased chance of leakage. Maneuvering to remove a larger, heavier or awkwardly shaped component often results in bumping, banging, leaning on or similarly disturbing adjacent piping and components.

Guidelines to minimize leakage

The following practices will help reduce the likelihood of pipe leakage.

Buy quality components. The adage "you get what you pay for" is very true for pipe and compression fittings. There is a reason why union or connector costs differ drastically from one supplier to the other. Components with lower initial costs will almost invariably turn out to cost more in the end when the costs of finding and repairing leaks are included. Quality always costs more, and many very low-cost fittings are sold primarily on price and are often of poor quality.

Select the proper components for the service. Make sure the tubing you purchase has the proper hardness. Confirm that all the piping components have an adequate pressure and temperature rating with an adequate margin above your highest operating conditions. They need to be suitable for those infrequent times that are hotter or cooler than normal. This is particularly relevant in exterior service, where failing to account for the few days a year above 100°F or below 0°F can create needless problems. Recognize that solar gain (the heat that metals will pick up when exposed to the sun) can be significant (10–30°F). Trying to locate fittings in the shade may help reduce issues but it will only help at best, not eliminate the issue.

Assemble fittings properly. Train all personnel on proper assembly techniques. Leaders should not assume that all personnel know how to assemble fittings correctly, or that they will carefully read the (often cryptic, or missing) instructions. These steps may seem like overkill, but they really do help prevent needless leaks. Gauge compression fittings after assembly to confirm proper makeup. The short time this takes pays rich dividends on showing which fittings need to be tightened. Mark the fitting to indicate the proper number of turns or make sure you have some way to always count them. Make sure the tubing is fully inserted into a compression fitting by either marking the proper insertion depth and making sure it goes in that far or disassembling the fitting to make sure it was done properly. Occasional checks after assembly are often prudent as a quality-control measure. Quality fittings come with the ferrules aligned and the nut just loose enough to insert the tubing. Try to avoid taking them apart before assembly. While perfectly acceptable, it does increase the chances of misalignment and should be avoided if possible.

Consider leakage in the design. Avoid problematic connections, such as pipe threads and pipe unions, particularly in heated or cooled lines or in gas service. Consider where flanges may be a better choice on larger lines and compression fittings on smaller lines (Figure 5). Allow reasonable access to all components and connections, not just the ones you think likely to leak, and particularly those that need higher maintenance. These include: pumps, compressors and similar rotating equipment; filters, purifiers and similar items that need to be cleaned or replaced; and all instrumentation. Some time and effort during the design stage produces much lower leakage rates.

Use holdbacks. Always use a holdback to keep adjacent fittings from being needlessly turned or stressed. Train personnel how to use it properly (Figure 6). This is something that sounds easy until you do it. Support all your valves, or at least all the valves you will turn with any frequency. Individual valve brackets work best, whether homemade or purchased. Supporting valves by clamping the tubing on each side is effective if the supports are close enough. Panel board mounting is not recommended. While it rigidly supports the valves, it is difficult to align all the tubing properly. This leads to frequently forcing it into place with increased risk of leakage. It also makes leak testing harder due to limiting access.

Consider custom fabrications to reduce the number of potential leak points. Waiting a few weeks for a vessel with exactly the ports you need, paying extra for a nonstandard fitting, asking for welded fittings instead of threaded, or specifying an instrument with integral compression fittings instead of adaptors almost always ends up costing less and being faster in the end. It does, however, require some thought during the design and procurement stage.

Minimize the number of joints. Fewer joints mean fewer potential sites for leakage. Bend more tubing instead of using elbow fittings. Use crosses instead of dual tees (four versus six potential leak sites). Purchase reducers that match exactly the sizes you need rather than using multiple fittings. Specifying valves with different inlet and outlet connections, gages with tubing connections, or instruments with tubing connections may cost a bit more and take somewhat longer for delivery,

FIGURE 7. The compressor should have a flexible connection as the fitting on the tank is certain to leak over time

but the savings in time and effort in finding and correcting needless leaks always outweighs these initial outlays. Consider in-house or custom fabricating those things you can't purchase. Machining specialty fittings, welding two stock fittings together, or getting a custom component manufactured is often feasible. The extra time spent and cost are always recouped quickly through reduced leak testing and locating and remedying leaks found.

Properly mount equipment. Make sure the mounting provides adequate strength to resist the forces that will be applied to it. How often have you seen tubing bent near a cartridge filter that required a wrench to remove or a valve that can be seen to move slightly when it is turned? Substantial-looking brackets can flex in unplanned directions. Often the support for the bracket is too flimsy and flexes. Supporting pipe or tubing to other pipe or tubing is a bad practice. While it can prevent sagging on long runs, it provides little support to prevent leakage.

Pipe removable components properly. Consider how you would assemble and disassemble any component that needs maintenance or changing such as filters, purifiers or traps. How do you remove instruments for calibration or control valves to replace trims? Plan on how you remove them without generating needless leaks. Zero-clearance fittings are well worth the extra cost. Flexible hoses and removable U bends often eliminate or at least reduce needless leakage. This may require extra space during the layout.

Isolate vibrating equipment with damping pads or springs. Flexible connections to fixed systems, such as compressors, pumps, vacuum pumps and mixers, are important for all piping (Figure 7). Make sure the supporting structure is stiff enough that it does not vibrate or flex during operation. Make sure that any residual vibration is dampened as much as possible. Do not anchor tubing supports to the rotating equipment stand. That usually just transmits the vibration even further.

Carefully design systems subject to temperature changes. Wherever possible, avoid or minimize joints. Instead, use welding, brazing or soldering to eliminate these potential leak points. Utilize specialty fittings and components with fewer joints. Use more leak-resistant components like vacuum fittings. Consider packless valves and similar "sealless" components. Avoid heat tracing if possible and consider small heated enclosures instead. These raise the temperature of all the internal components at a similar rate and minimize leaks due to uneven thermal stresses. Heated enclosures will, unfortunately, still result in piping leaks upon cooling or other temperature changes, but will avoid numerous routine temperature differentials that are always produced by heat-tracing systems. These differentials are certain to increase the number of leaks. The use of heated enclosures also allows modification, leak testing and maintenance without insulation removal and replacement — another cost savings.

Consider keeping the system at a constant temperature when not in service. The extra expense associated with doing so is often more than offset by a reduced leak rate. Provide for gradual heat up or cool down — the slower, the better. Automating the process to slowly ramp up or down over time is often a good way to implement this method. Allow for expansion and contraction, even in shorter runs.

Is it possible to implement all of these suggestions all the time on all your units? Sadly, in the real world, probably not. You likely will not have enough space, money or time to always do everything 100% correctly 100% of the time. But by following these guidelines as much as possible, you can make significant improvements in reducing pipe leakage. ■

Edited by Scott Jenkins

Author

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Part 2

Pipe Supports: Challenges and Solutions

Pipe supports in industrial process plants are often more complicated than commonly thought. Presented here are some of the challenges that can arise and how to address them

Scott Feller
AMG Inc.

IN BRIEF

THERMAL EXPANSION OR CONTRACTION

PIPE-INDUCED FORCES ON EQUIPMENT

ANCHORS, GUIDES AND SLIDES

PRACTICAL PIPE SUPPORTS

On one level, the topic of pipe supports seems like it should be simple: support the pipe. And sometimes, it is that simple, but most often, it is not. In industrial processing plants, regardless of the process or utility, there are a myriad of considerations when it comes to pipe supports. Concerns such as maximum allowable span for stress, deflection, vibration, harmonics and thermal growth need to be addressed, as well as the interaction among the pipe, its supports and the structures that support those supports. What happens when pipes of various materials of construction, with different allowable stresses, and operating at different temperatures share a common pipe rack? When these conditions are thoroughly considered, proper pipe supports can become more complicated.

This article discusses various pipe-support challenges and some ways to overcome those challenges. It will also point out examples of supports that are either ineffective in the way they are utilized, or much more expensive to install than a simpler approach would be.

Thermal expansion or contraction

Situations involving thermal expansion and contractions of piping are very common in steam and condensate systems, chilled water and cryogenic applications, and in many other process-piping systems. These pipe runs can present multiple challenges, including high anchor loads, nozzle loads on equipment, expansion-loop geometry, or expansion joint selection and placement. The trick is to choose the anchor points wisely. Often, it is necessary to create anchors close to (within 20 feet or so) connecting equipment, such as tanks or pumps, so that the thermal expansion or contraction between the anchor and the equipment can be minimized and more easily controlled with supports, flexible legs, flex joints, springs and so on. The longer runs between these end anchors can be challenging, particularly in congested pipe racks. If expansion loops are necessary, they may block the routing of adjacent lines. Using an up-and-over loop may solve that problem, but might also prevent pipe drainage, require additional steam traps or interfere with other piping, ductwork or electrical runs above. Linear or axial expansion joints might be an option, but care must be taken to address the pressure-induced thrust that might occur. Pressure-balanced (or compensated) expansion joints are a good option, but can be expensive. Ideally, if the pipe run has changes in direction, they can be utilized as flexible legs to allow growth or contraction, as illustrated in Figure 1. The expansion or contraction distance must be determined to properly space adjacent pipes.

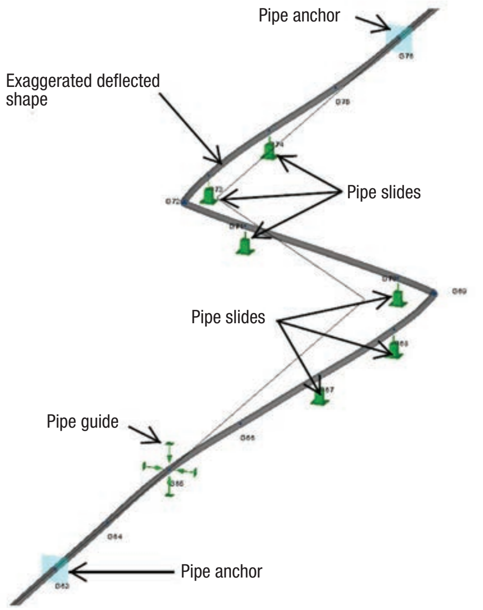

FIGURE 1. Long pipe runs can be complicated by thermal expansion and contraction, and the distances must be determined

Pipe-induced forces on equipment

Process equipment, particularly devices with rotating components, such as pumps and compressors, are sensitive to forces applied by piping. Reduced seal life and premature bearing wear can result from large forces applied to nozzles. Atmospheric tanks and

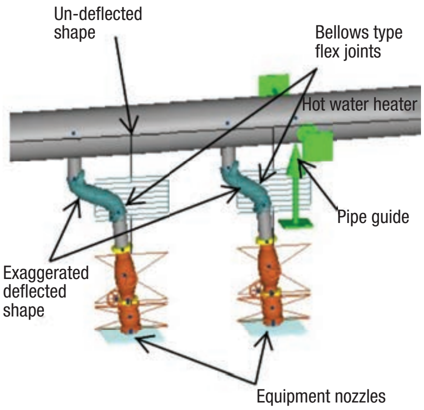

FIGURE 2. Expansion joints can reduce the loads on equipment nozzles

pressure vessels also have load limits. Loads due to gravity from small-bore piping are generally not a major concern, but loads induced by thermal expansion can be enormous. There are several strategies to reduce these nozzle loads:

1. Create changes of direction in the piping design to allow flexibility and reduce forces
2. Consider designing cold spring into the piping during installation
3. Evaluate the use of spring hangers or supports to reduce thermal and gravity loads across different load cases
4. Consider flexible mounting of the process equipment. Often, high forces can occur on a pump suction — for example, when it is directly connected to a tank with a straight piece of pipe. While the thermal growth or contraction of the pipe segment may only be a small fraction of an inch, the force required to resist the force generated by the expansion can be tens of thousands of pounds. Allowing the pump to float by a 1/16th of an inch can reduce the reaction to a negligible level. This can be achieved by mounting the pump on spring mounts, on a slide base or on threaded rods, allowing them to bend.
5. Expansion/flex joints are an option to reduce loads on equipment nozzles. Unfortunately, they are often incorrectly applied. Due to the pressure thrust forces created by the joint, it is very unlikely that a straight bellows-type flex joint intended to allow axial compression will resolve forces on the pump suction example above, unless the maximum pressure that the system will experience (which is typically test pressure) is very low. These types of joints can be very beneficial, however, in a lateral-displacement configuration, as shown in Figure 2.

Sometimes space constraints can complicate supports near equipment, and out-of-the-box solutions need to be found. The images in Figure 3 show supports at pump suctions in a hot-oil system, where the pipe needed to be controlled both laterally and vertically, but also needed freedom to grow away from the pump suction.

Anchors, guides and slides

Anchors are critical components in any large piping system, and are intended to resist movement from all forces in every direction. They establish the boundaries and the control conditions for all other pipe-stress and support analysis. Anchors are interesting in that they are not just designed to support applied loads, like hangers and guides. Instead, they need to be evaluated for rigidity or stiffness. For example, if an anchor is attached to the top flange

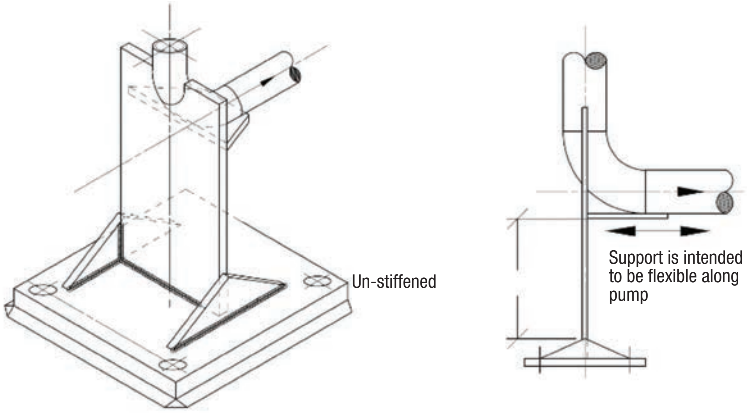

FIGURE 3. Pipe supports can allow lateral and vertical control, while also allowing freedom to grow

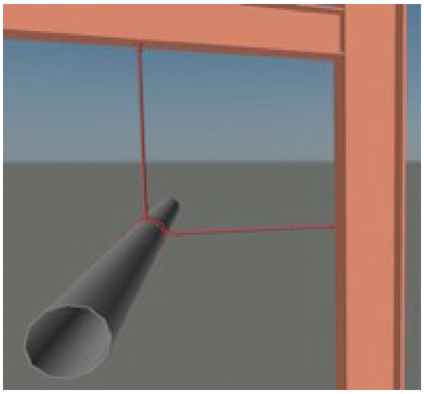

FIGURE 4. Pipe clamps and braces can provide support in two directions, while also allowing axial movement

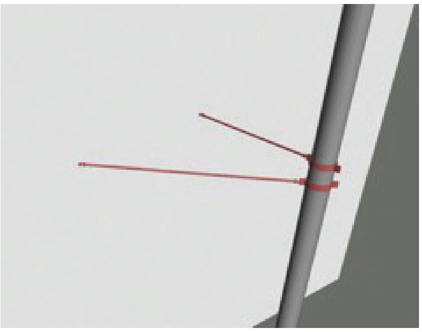

FIGURE 5. Axial movement can occur via the slight bending of the two-force guides

of a wide flange beam, the stiffness of that anchor is questionable. Weak axis bending and torsional instability of the beam may reduce the effectiveness of the anchor. If the anchor isn't relatively rigid, then all other stress and displacement calculations based on that anchor location may be called into question. In designing an anchor, it is critical that the anchor and the structure supporting it are evaluated together to ensure they interact together to achieve the desired performance.

Guides are applied to allow axial movement, generally due to thermal expansion or contraction, and to restrict lateral movement due to wind loads, plant vibrations, or even seismic forces. When a pipe is running along a pipe rack with regularly spaced support beams, the selection and evaluation of the guides is simple. For these situations, many off-the-shelf guides from pipe manufacturers exist. Selecting guides for some other conditions can be more challenging — for example, a pipe running a few feet below roof steel, or vertically a couple of feet off structural steel. In these instances, an off-the-shelf catalog guide probably won't work without incurring significant costs in additional structural steel. A low-cost solution for examples like these is to use pipe clamps, and either angle iron braces or threaded rod and turnbuckles to create two-force members that provide support in two directions, but allow axial movement via the slight bending of the two-force members (Figures 4 and 5).

Slides are applied in very similar instances as guides and are typically used together in thermal expansion and contraction applications. Slides provide support in one direction (generally perpendicular to the pipe), most commonly supporting a horizontal pipe from below. Like guides on a pipe rack with regularly spaced beams, slides can be selected in a straightforward manner, and there are many off-the-shelf slides available. They are typically selected to allow two degrees of freedom, usually lateral and axial. But once again, in instances where there is not a uniform framing level to support the slides, the alternatives must be investigated. In many cases, a simple clevis hanger can be used, as long as the hanger rod is long compared to the expected displacement of the pipe.

FIGURE 6. A tall post with a pipe slide, guide or anchor at the top is likely to experience relatively large deflection at the top

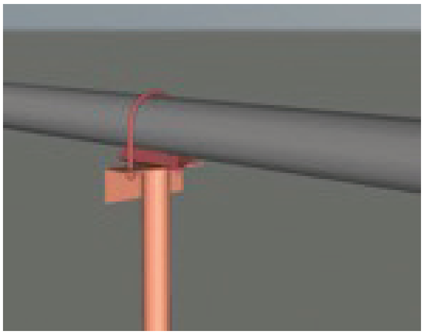

FIGURE 7. If the post can tolerate bending, then a U-bolt clamp may work as a pipe support

Practical pipe supports

Taking a practical approach to pipe supports can simplify the design of the support system and can usually make supports less expensive. The following are some examples of not-so-practical supports, along with a brief explanation as to why they are impractical, and a better alternative to the example.

Tall post with pipe slide, guide, or anchor on top. A tall post is likely going to experience a relatively large deflection at the top, depending on the section properties of the post, and even with a polytetrafluoroethylene (PTFE; Teflon) or ultrahigh-molecular-weight (UHMW) polymer slide or guide, there is still a friction force that will be applied to the post (Figure 6) .

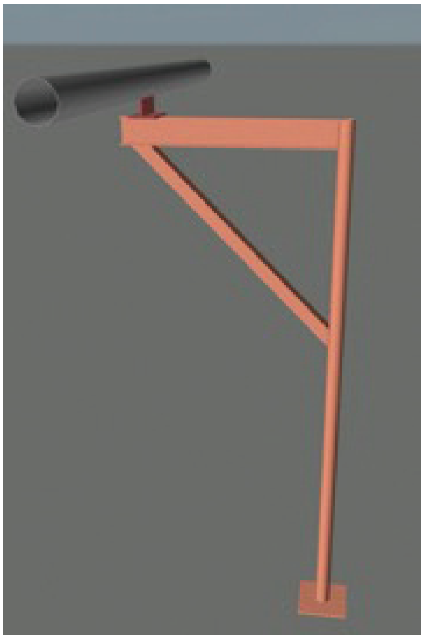

FIGURE 8. One concern surrounding tall posts with cantilevers involves the torsion of the post

The practical approach is to evaluate the expected displacement that necessitated the slide or guide, and check to see if the post and its bottom attachment (weld or base-plate anchors) can tolerate that deflection and bending moment. If it can, then the slide or guide is likely not needed, and a simple U-bolt might suffice (Figure 7).

In the case of an anchor on a tall post, the anchor needs to be evaluated for the stiffness of the post to make sure the resulting deflection doesn't create issues in the rest of the piping system. And again, a U-bolt may be able to transfer all the load the post can handle. Buckling stability of the support needs to be taken into consideration in all cases, but especially if the post is not a closed section member.

Tall post with a cantilever, and either a pipe slide, guide, or anchor. This case is very similar to the one just described, and is commonly seen in retrofitted or expanded plant areas. The principles are the same, but with torsion of the post added (Figure 8).

The support is likely flexible enough that slides or guides are not necessary, and this can easily be proven by comparing the expected displacement of the pipe to the deflection resulting from the calculated friction force from the slide/guide. If

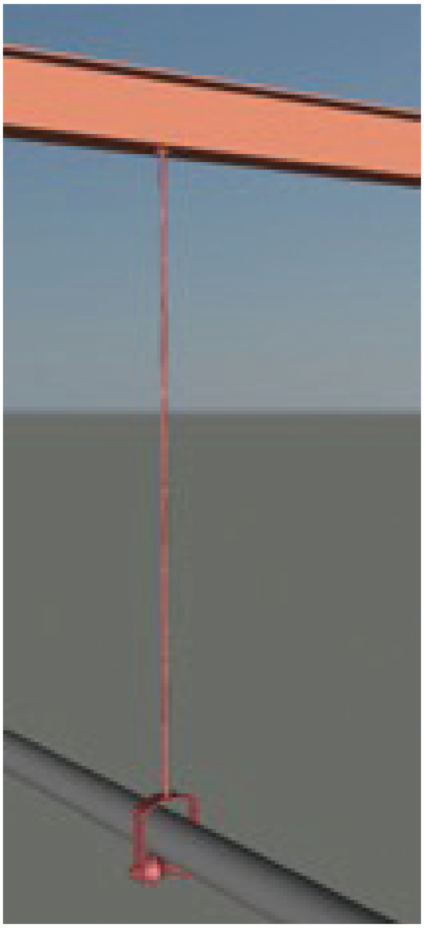

FIGURE 9. The stiffness of a rod hanger, like the one shown here, likely will not provide the resistance for the roller to roll

the friction force is enough to deflect the support to a degree that is equal to or greater than the anticipated pipe displacement, then the slide or guide should not be needed, because the support will bend before the slide or guide begins to move. Again, buckling stability of the support needs to be taken into consideration, especially if the post is not a closed section member.

Long threaded rod hanger and adjustable pipe roller. This is another case that is commonly seen, and like the case of the tall post, the stiffness of the threaded rod hanger is likely not enough to provide the resistance needed to cause the roller to roll, so the roller will just act as an expensive clevis hanger (Figure 9).

Pipe support design and engineering, like all other areas of engineering in an industrial plant, can be challenging. With a little understanding of the various situations, and by not always resorting to an off-the-shelf solution, the design can often be made simpler, more reliable, less expensive and easier to install. ■

Edited by Scott Jenkins

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Rapid Maintenance Response: When Plants Can't Wait

Even with advanced predictive technologies, unplanned equipment failures can still occur. In these instances, as shown in this boiler example, rapid maintenance action is crucial to minimize downtime

Adam Crosswell
Sulzer Chemtech

IN BRIEF

WHEN EQUIPMENT REACHES A BOILING POINT

THE POWER OF AUTOMATION

GOING THE EXTRA MILE

Maintenance activities generally fall into two categories — reactive and preventative. The first focuses on repairing an asset once a failure occurs, while the second aims to avoid asset failure and repairs by preventing issues before they happen. Such preventive measures are achieved by using predictive methods that leverage theoretical rate of failure and actual equipment performance.

In an ideal world, rather than relying on reactive maintenance, a chemical processing plant will employ planned preventative activities to minimize downtime. However, in practice, unexpected equipment failures do happen, resulting in unplanned shutdowns and turnarounds. Businesses can still make the most of the circumstances by promptly adjusting their maintenance schedules to bring forward equipment-optimization projects. To succeed in this strategy, comprehensive, responsive maintenance practices are needed to support businesses.

High-quality predictive models enable businesses to plan suitable maintenance schedules that maximize equipment lifespans while minimizing the environmental impact, costs and downtime associated with replacing damaged units or components. Accurate and reliable simulations of equipment or component failure are a key asset. However, machines can sometimes still experience unexpected issues.

In these situations, it is crucial for facilities to be as flexible as possible, readjusting their maintenance schedules and intervening quickly to restore optimum operations with minimal downtime. In addition, they can turn the situation to their advantage, using the shutdown to complete regular maintenance activities that were scheduled to take place at another time. In this way, plants can maximize their annual uptime. To outline such responsive strategies, a maintenance project involving boilers at a real-life waste-to-energy plant is used as an example in this article (Figure 1), but these maintenance principles are applicable to any type of boiler that is exposed to harsh conditions.

FIGURE 1. The unplanned failure of boiler equipment required the rapid restoration of the boiler's structural integrity to help restore its operations quickly

FIGURE 2. Boiler inspection led to the recommendation to clad, or weld overlay, the damaged areas

When equipment reaches a boiling point

The waste-to-energy plant referenced in this article incinerates 750,000 metric tons of residual municipal solid waste (MSW) per year, which would otherwise be sent to landfill. The heat generated by the process is used by boilers to heat water and produce steam.

Boilers — critical equipment in waste-to-energy plants, and many other types of processing units — are regularly exposed to harsh operating conditions. For example, in boilers, waste with large volumes of plastics, or materials containing paint or glue, will generate a broad range of volatile compounds containing chlorine, sulfur, alkali and heavy metals, as well as hydrochloric acid and chloride salts. The presence of various impurities in the combustion gases can cause ero-

FIGURE 3. Weld overlay involves applying layers of corrosion-resistant materials onto the selected surfaces

sion and corrosion of the furnace and wall tubing. Both types of damage can be exacerbated by chloride-rich ashes that inhibit the growth of a dense, duplex oxide scale on the boiler's surface, which would ordinarily act as a diffusion barrier to prevent or reduce corrosion and erosion. Additionally, alkali metals, lead and zinc can react readily with chlorine and further contribute to the transport of chloride-rich ashes to the boiler tube's metal surface, increasing the corrosivity of the deposit. Finally, heat flux in boilers leads to the rapid diffusion of corrosive substances.

All of these factors serve to decrease the useful life of boilers in processing facilities. Nonetheless, proper boiler maintenance prevents these issues from escalating and causing cracks, ruptures, thermal fatigue or other factors that can further shorten the unit's lifespan, affecting reliability and performance of all plant operations. Also, highly effective maintenance strategies can help facilities by optimizing performance and productivity.

In accordance with these goals, the waste-to-energy plant scheduled regular maintenance of its three boiler lines to maintain optimal boiler and plant performance, and also planned a turnaround for one of its boiler lines.

However, the facility experienced an unexpected failure on that line well before its scheduled downtime. To avoid having two periods of downtime on the same equipment within one year, it was necessary to conduct the planned maintenance activities at the same time as the emergency repair.

A team of maintenance engineers assessed the condition of the boiler, which was found to be eroded and corroded (Figure 2). After abrasive grit-blasting operations were conducted on the structure to remove impurities from the eroded surfaces, the team evaluated the state of preservation of the vessel. Together with tube-wall thickness readings, the engineering team could offer a quantitative analysis on the level of corrosion and erosion in the equipment and determine the best course of action.

Further work found heterogeneous conditions across the tubes, with areas where the thickness was compromised, but above 2.5-mm thickness, and others that were more heavily eroded or corroded, with thicknesses as low as 2 mm.

To restore the structural integrity of 60 m^2 of membrane walls within the boiler, where thicknesses above or equal to 2 mm were found, the suggestion was made to clad, or weld overlay, the structures (Figure 3). This method relies on the application of layers of corrosion-resistant materials, such as Inconel 625, an austenic nickel-chromium-based superalloy containing niobium, on damaged areas in existing units

Inconel 625 is particularly durable and resistant to corrosion, erosion and oxidation, even in harsh environments with elevated temperatures, such as in boilers. More precisely, the chromium component in the material provides resistance to oxidizing chemicals, while the high nickel and molybdenum content make the alloy resistant to non-oxidizing environments.

Molybdenum also makes the material particularly resistant to pitting and crevice corrosion. The added niobium stabilizes the alloy against sensitization during welding, thereby preventing subsequent intergranular attack. Also, the high nickel content protects against stress-corrosion cracking caused by chloride ions, which are typically found in incinerated waste. In addition, Inconel 625 exhibits high fatigue strength, even when it is present in the form of thin sheets.

Moreover, the thermal conductivity of Inconel 625 is lower than that of carbon steel, so the application of thin layers is ideal to avoid any increase in surface temperature that would promote corrosion while optimizing heat exchange for elevated boiler performance. As a result, this alloy would allow the boiler's surface to better withstand its extreme operating conditions and increase its lifespan.

The power of automation

To streamline the process, the maintenance engineers leveraged automation to perform the weld overlay procedures. By doing so, the project could be completed at least three times faster than using manual cladding, helping the plant to reduce the shutdown interval and re-start operations faster.

For automating such a task, robotic arms can be used in welding activities to create weld beads on a surface that needs repairing (Figure 4). The robot is moved along the damaged area on a carriage, which travels on a laser-leveled track system fixed to the boiler's surface. All the weld-overlay process parameters, such as carriage speed and bead thickness, are controlled by a programmable logic controller (PLC; Figure 5).

The control unit also stores different weld procedures, meaning that operators can easily select and monitor the best procedure on the basis of the intended application via a human-machine interface (HMI), without the need to qualify and test new procedures. Establishing new weld procedures could otherwise require up to four weeks. So, utilizing proven, standardized setups helps substantially reduce downtime and address emergency shutdowns as quickly as possible.

FIGURE 4. To restore the integrity of the boiler's wall, a robotic arm was used to move a welding torch and an oscillator, creating weld beads. The robot is moved along the damaged area by a carriage, which travels on a laser-leveled track system fixed to the surface that needs repairing

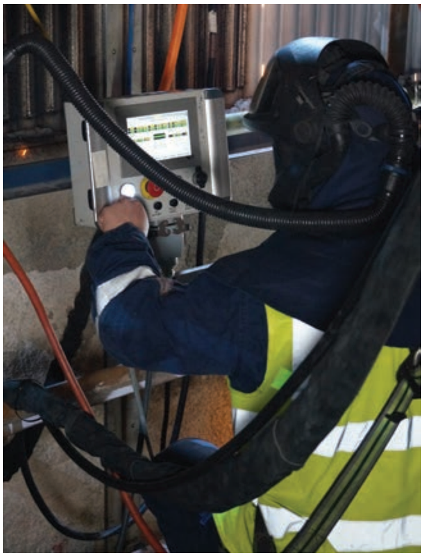

FIGURE 5. Advanced automation technologies can contribute to more rapid resolution of maintenance and repair tasks

Going the extra mile

The strength of the boiler tubes with thicknesses between 2 and 2.5 mm were also enhanced before the automated weld overlay to obtain optimum results. These parts, which accounted for 3 m^2 of the total surface area, were pre-treated by means of carbon-steel buildup. This consists of applying a layer of parent material to the existing tubes before coating the surfaces with refractory Inconel 625.

Once completed, the repair passed independent non-destructive tests (NDT) to evaluate the quality of the procedure. In particular, suitable, homogeneous thickness levels were found using direct-thickness checks. Similarly, dye penetrant inspection (DPI) unveiled the absence of surface-breaking flaws and discontinuities that could otherwise compromise erosion resistance and equipment service life. Even more, positive material identification (PMI) analyses revealed a suitable elemental composition of the weld overlay.

A thorough final inspection report was provided, detailing the general conditions of the boiler that the plant could use to effectively set up future preventative-maintenance activities. In addition, this confirmed the quality and compliance with key requirements and regulations. The combined repair and maintenance projects were completed in only twelve days of downtime and the plant could restore operations at its boiler line.

When unexpected equipment failures occur, the top priority for businesses is restoring their operations as quickly and as effectively as possible. A skilled maintenance and repair specialist plays a key role in enabling plants to meet these goals. In particular, a team with the right expertise can streamline these activities by quickly mobilizing teams, offering rapid consultations and feedback, as well as leveraging experience and advanced solutions to shorten processing times. ■

Edited by Mary Page Bailey

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Methods For Testing Steam-Trap Stations

Testing steam-trap stations can be very easy if the plant provides the correct equipment, training and commitment to the steam-system management program

Kelly Paffel
Inveno Engineering, LLC

IN BRIEF

FIGURE 1. Shown here is a visual indicator on a steam trap

FIGURE 2. A steam trap test valve is shown here

When it comes to testing steam traps, a frequently asked question is, "what is the best method?" The true answer is to use all of the technologies available today. No single test method provides the best results all of the time for the variety of applications, installations and steam-trap types in industrial plant operations. Therefore, all tools available in the marketplace should be implemented and used where appropriate. So, what are these tools? They can be segmented into three categories:

- Visual
- Temperature
- Ultrasound

Becoming proficient with these tools is like riding a bicycle — the more you ride the bicycle, the better you become. Practice and gaining the knowledge of the methods is the key to successfully using the different devices.

VISUAL METHODS

The use of a testing-tee valve arrangement, testing-valve combination, or an inline sight glass for reviewing the steam trap discharging to the atmosphere is a very effective way of testing steam traps (Figures 1 and 2). This visual method can accurately determine the following conditions:

- Blow-through steam or a failed open condition
- Severe steam leakage
- Under-sizing

There are some negatives to any testing method and the visual method is no exception. The inspector must understand the concept of flash steam and become aware of the difference between flash steam and blow-through steam. There are safety concerns due to the release of hot steam to atmosphere during the testing phase. Finally, there is a small additional cost associated with installing the components that permit online testing.

TEMPERATURE METHODS

The relationship between steam pressure and temperature makes temperature measurement extremely helpful in understanding many different operating conditions of steam components that are found in the steam and condensate system.

Infrared (IR) temperature measuring is a very quick and versatile tool for steam systems. Like all testing equipment, IR requires training to ensure success. All diagnostic tools have positive features and negative attributes. It is important to understand the negative attributes to ensure an accurate temperature measurement.

Temperature measurement devices must be an integral part of a steam-trap station

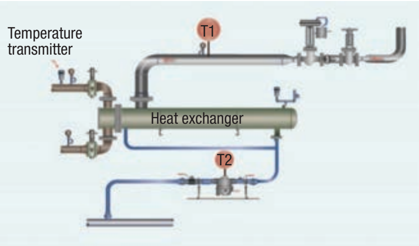

FIGURE 3. Measuring the inlet and discharge temperatures can provide an estimated steam pressure

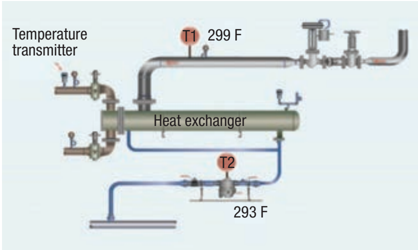

FIGURE 4. In this setup, the steam inlet and steam-trap temperatures are equal or nearly equal

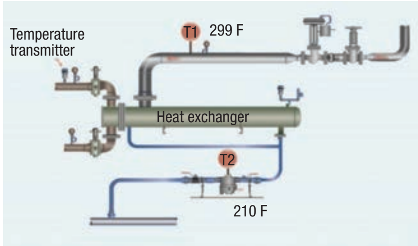

FIGURE 5. In this example, the steam trap has a low body temperature

testing program. These devices are by no means the only piece of diagnostic equipment that should be used, but they can help provide valuable information that would otherwise not be available.

Estimating steam pressure

Plant engineers can estimate steam and condensate pressures by using temperature-testing devices to detect the temperature of the steam line inlet to the steam-trap station and on the discharge line (Figure 3).

Knowing what steam and condensate pressures are present in the system will assist the people performing the steam-trap station testing, enabling them to quickly evaluate system dynamics that can affect the steam-trap station's operation.

Is the steam trap operational?

A temperature measurement will allow the steam-trap station examiner to determine whether the steam trap is operational or whether the steam trap station is below the expected temperature. If the latter is the case, then the plant should initiate root-cause analysis to determine the source of the problem in the system.

For example, in Figure 4, the temperature on the steam line entering the process is 299°F; therefore, the steam-trap body temperature should be at or close to the inlet temperature.

This is a true statement for 96% of the steam process applications. However, there are a few exceptions when the heat-transfer units have an extremely high condensing rate or when there is a pressure drop in the process. The following three examples make this more clear.

Example 1: Equal temperatures. The inlet and outlet temperatures (process and steam trap) are measured to be the same or nearly equal (Figure 4). This means the steam trap is operational, and further testing can be accomplished.

Example 2: Low outlet temperature. In Figure 5, the steam trap body temperature is very low (210°F) compared to the inlet steam temperature to the process. The steam trap temperature is low, and root-cause analysis needs to be performed to find the reason, such as the following:

- Undersized steam trap
- Fouled strainer
- High back-pressure in the condensate line
- Other causes

Testing steam trap performance

Although surface-temperature measurement can be very useful in evaluating various potential conditions, using it alone for testing steam-trap stations will have a low accuracy for testing steam trap performance. A steam-trap station examiner should be extremely knowledgeable of steam and condensate system dynamics.

Different sources state that if there is a high temperature differential across the steam-trap station, then the steam trap is in good operational condition. If there is no or a very low temperature differential, then the steam trap has failed and is blowing or leaking steam into the condensate system. Temperature measurements must be part of the steam trap station standard operating procedure (SOP) to ensure the steam trap station is operational.

Example 3: High temperature differential across the steam-trap station. Figure 6 indicates a high temperature differential (inlet temperature = 299°F; outlet temperature = 214°F). However, the steam trap is completely failed and is blowing steam into the condensate line. Then why is there a high temperature differential?

If steam is blowing into a condensate line that has zero pressure, the steam temperature of the blowing or leaking steam trap must be at 212°F, or the temperature of steam at zero pressure. Now, when the steam passes from a high pressure to a lower pressure, superheat will be generated, but the condensate passing the steam keeps the steam at saturated conditions.

Example 4: Steam-trap station with a low temperature differential. Figure 7 shows a very low temperature differential (inlet temperature = 299°F; outlet temperature = 284°F), which should indicate that the steam trap has failed and is blowing steam in the condensate line. In this example, there is backpressure in the condensate return line, which is normal in most condensate lines due to design, undersizing and elevations. The condensate line pressure will vary depending on the variables. With pressure in the condensate line, the condensate line temperature should be at or close to the saturated temperature at the condensate line pressure.

Example 5: Low-pressure systems. There will be a low temperature differential across the steam trap station based solely on the low steam pressures in the steam system and condensate line, as shown in Figure 8. The steam trap could be failed or working properly; the condition of the steam trap is unknown because both conditions will have similar steam temperatures.

Measurement procedures

Temperature measurements (Figure 9) need to be taken upstream and downstream of the steam trap station

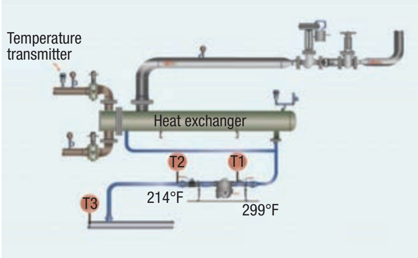

FIGURE 6. There is a high temperature differential across the steam trap shown here

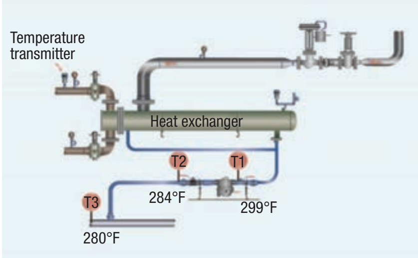

FIGURE 7. This example shows a low temperature differential across the steam trap

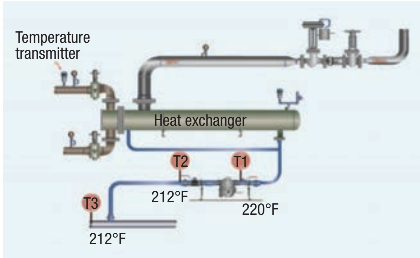

FIGURE 8. There is a low temperature differential across this steam trap station at low pressure

to determine the inlet steam pressure to the steam trap station and the condensate line backpressure.

To achieve a representative temperature, scan the exposed metal surfaces of the upstream and downstream piping/tubing around the steam trap station. Some installations may have several inches exposed, while other installations may only have pipeline components, such as unions, valves or fittings, exposed. The steam-trap station examiner must consider what is available for temperature scanning when incorporating the temperature reading in evaluating the steam trap station operation. The following are suggested:

- Measure the inlet temperature of steam/condensate line to the inlet of the steam trap. A significantly lower temperature than the saturation temperature of the steam line pressure can indicate that there are issues with the steam trap, that flow is reduced due to plugged fittings or strainer screens, or even that the steam trap has been valved off
- Measure the temperature to the inlet of the steam consumer (equipment) and compare it to the inlet of the steam trap. Generally, these temperatures should be close in measurement (±20°F/±11°C)
    - ❍ Record the reading
- Measure the outlet temperature in the condensate line downstream of the steam trap
    - ❍ There should be some decrease in the outlet temperature versus the inlet temperature
    - ❍ This measurement can also be used to determine the backpressure present in the condensate line
    - ❍ Record the reading

In concluding this section, we can say that temperature measurement is an important part of steam-trap station evaluation, but it is only one of the methods. Others are important, too.

ULTRASOUND

When using high-frequency ultrasound, the main question is where the sensitivity should be set to conduct the test. If the testing instrument is set with a sensitivity that is too high, all of the steam traps will test as failed; using too low a sensitivity will indicate that all steam traps are operating properly.

The solution is using a field-proven comparison method, which will provide an accurate test on each steam trap. The comparison method uses three or more test points on the steam trap station. Two of the test points are the sensitivity baseline settings on the ultrasound unit, and the third is for testing the steam trap. The comparison method allows the steam-trap station assessor to establish a base reading to filter out any competing ultrasounds that can be generated upstream or downstream of the steam trap. Without using the comparison method of testing, it is very difficult to assess the steam trap's performance because the assessor will not know the correct sensitivity setting. Each steam trap will be in slightly different installations and situations in the steam system, so the comparison method is the most accurate method for setting the ultrasound sensitivity.

Sensitivity settings

Most digital ultrasound devices have a stethoscope module. With the stethoscope module, contact each point on the steam trap station, as shown in Figure 10. The steam and condensate line should have baseline test points that are between 6 and 10 in. upstream or downstream of the steam trap that is being tested. More test points can be taken to establish a baseline, but at least two need to be done for each steam trap location (these estimated values will vary depending on the piping).

FIGURE 9. A temperature measurement is being performed in this picture

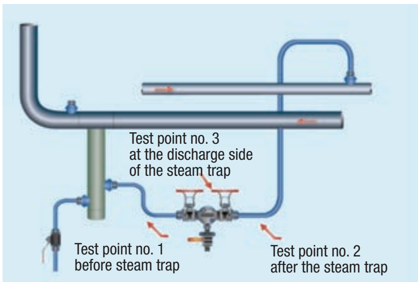

FIGURE 10. The three test points shown here are used to establish a baseline for ultrasound testing

FIGURE 11. Shown here is a dial reading of a typical ultrasound unit

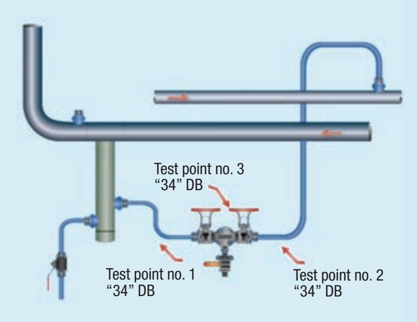

FIGURE 12. In this example, the ultrasound levels at Test point 3 are equal or less than Test points 1 or 2

Setup and operation

The ultrasound unit needs to be set at 25 kHz to provide the highest clarity for high-frequency ultrasound generated by steam or condensate passing through an orifice in a steam trap. The following steps outline a typical operation procedure:

1. Pull the trigger to turn on the ultrasound unit. If the instrument is within sensitivity range, the decibel (dB) indicator (A in Figure 11) will blink.
2. The decibel reading should be set to 20 dB.
3. The kHz (frequency) indicator must be steady and not blinking (B in Figure 11). If the kHz is blinking, then it is in the adjustment mode for frequency. Adjust it to the correct frequency level and push in the sensitivity knob to return to the sensitivity adjustment-setting mode.
4. Once in the sensitivity mode, turn the sensitivity control dial clockwise to increase the sensitivity and counterclockwise to decrease the sensitivity.
5. The sensitivity control dial increases or decreases the sensitivity of the instrument simultaneously with the sound level in the headphones (NOTE: The instrument needs to be in range for accurate testing).

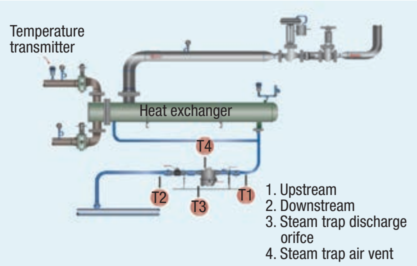

FIGURE 13. The four test points shown here are used for testing float and thermostatic steam traps

6. If the sensitivity is too low, a blinking arrow pointing to the right will appear, and no numeric decibel level will be visible in the display panel. If this occurs, increase the sensitivity until the arrow disappears. (In low-level sound environments, the arrow will blink continuously, and it will not be possible to achieve a dB indication until a higher intensity level is sensed.)
7. If the sensitivity is too high, a blinking arrow pointing to the left will appear, and no numeric decibel value will be visible on the display panel. Reduce the sensitivity until the arrow disappears and the numeric decibel value is shown.

Testing methods and results

What follows are a few examples of some tests for comparison.

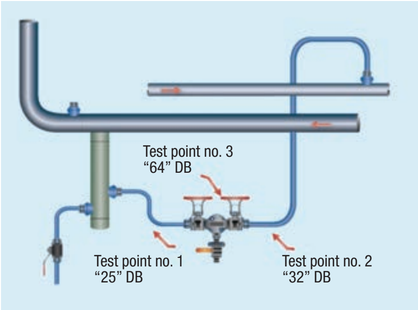

FIGURE 14. Measurements at three test points indicating a failed steam trap

Proper Operation (PO). Using Figure 12 as a guide, consider the following three measurements:

Test point 1:	32 dB
Test point 2:	34 dB
Test point 3:	**34 dB**

If a steam trap is operating properly, the ultrasound level at Test point 3 will not be higher than at Test points 1 or 2.

NOTE: The reading at Test point 3 will be equal or less than the readings at Test points 1 or 2. The high-frequency ultrasound readings, in addition to a temperature measurement that is appropriate for the system pressure, will indicate a properly operating steam trap.

NOTE: If the ultrasound reading at Test point 3 is higher than the readings at Test points 1 or 2, wait for 45 seconds to ensure that the steam trap was not in a cycle mode. During the cycle mode, the ultrasound reading at Test point 3 will be higher, which is the proper operation of a steam trap with on/off discharge cycle.

Float and thermostatic steam traps: Four test points. The float and thermostatic steam trap has two orifices: one orifice for discharging the condensate and the other orifice for the air vent mechanism that discharges air and non-condensable gases.

The four test points, shown in Figure 13, are as follows:

T1 — upstream of the steam trap station,

T2 — downstream of the steam trap station,

T3 — at the discharge side of the steam trap condensate orifice, and

T4 — at the discharge side of the steam trap air vent.

NOTE: If the air vent is operating properly, the ultrasonic level at Test point 4 (T4) should be equal to or less than Test point 3 (T3). If T4 is higher than T3, then the air vent mechanism has failed.

Blowing or completely failed steam trap (BLW). For this example, the three test points indicated on Figure 14, are as follows:

Test point 1:	25 dB
Test point 2:	32 dB
Test point 3:	**64 dB**

A significant increase (greater than two times the base level reading) in the decibel level at test point 3 indicates that the steam trap is failed open and allowing steam to pass. Continue to monitor the steam trap at test point 3 to see whether the steam trap cycles according to its design.

Steam leakage. When a steam trap system is leaking steam, the following test points, shown in Figure 15, should be considered:

Test point 1:	25 dB
Test point 2:	32 dB
Test point 3:	**49 dB**
Test point 4:	40 dB

An increase in the decibel level at Test point 3 indicates leaking steam through the steam trap. Again, if this increase is observed, take additional time at test point 3 to determine whether the steam trap is in the middle of a discharge cycle. If the decibel level at Test point 3 does not return to the baseline value established at test point 1, then the steam trap is leaking steam.

Competing downstream ultrasounds. Consider the five test-point measurements shown in Figure 16, in which all the steam components are tested:

Test point 1:	22 dB
Test point 2:	42 dB
Test point 3:	28 dB
Test point 4:	28 dB
Test point 5:	**52 dB**

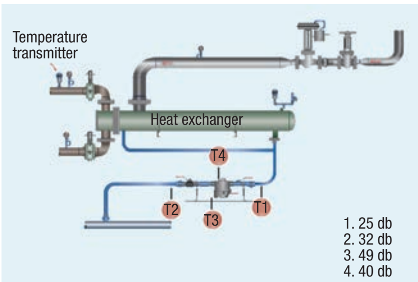

FIGURE 15. Measurements at these four test points indicate a steam trap leaking steam

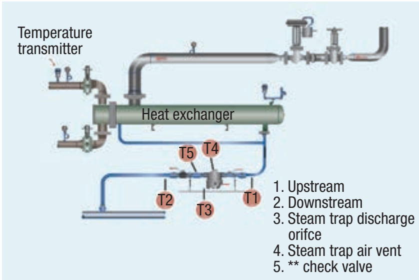

FIGURE 16. Utrasound testing of all steam components requires these five test points

The above readings show that ultrasound is being produced downstream of the steam trap. Check valves can be a source of additional ultrasound in the piping system. Perform further testing at the other components in the steam trap station (Test point 5) if the assessor determines that the check valve in the system is generating the high ultrasound levels. If the decibel value is higher at Test point 5, then there are competing ultrasounds in the system. If the value is lower at Test point 5, conduct further examination of the piping and steam trap to determine the source of the higher ultrasound.

Sound characteristics

While using ultrasound listening devices, the tester should be made aware of a few distinct sounds that he or she may hear while testing steam traps:

- Crackling — This sound signature is generated by condensate flowing through a steam trap with flash steam occurring after the discharge orifice of the steam trap
- Whistling — A whistling sound is a characteristic of steam passing through a steam trap orifice ■

Edited by Gerald Ondrey

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Evaporators: Energy Conservation Strategies and Process Control

Several strategies for improving energy consumption and process control in evaporation processes are presented here

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In industrial evaporation, a heat source (usually condensed steam) is used to concentrate a material through the removal of a liquid solvent. There are several types of evaporators and a number of important design principles. This article describes techniques to reduce energy usage in industrial evaporation, and also control methods for evaporators. For more information on evaporation fundamentals and equipment selection, please see Ref. [*1*].

Multiple-effect evaporators

To a first approximation, the heat obtained upon condensation of 1 pound (lb) of steam is enough to evaporate 1 lb of water, leading to an expected steam economy of about 1 lb of water evaporated per 1 lb of steam for an ordinary evaporator. However, the evaporated vapor also contains latent heat of vaporization. Rather than releasing this heat to cooling water flowing through the condenser, why not use it to evaporate more water? Such an arrangement is shown in Figure 1 for a double-effect evaporator. Note that in Figure 1, the temperature in the first effect (T_1) is greater than that in the second effect (T_2), as required to provide the driving force for heat transfer in the second effect, and the effect pressures also correspond so that $p_1 > p_2$.

The feed is partially concentrated in the first effect, then the first-effect product is directed to the second effect for final concentration. The heat source for the first effect is steam from the boiler (or a waste-heat source), while the second-effect heat source is the vapor produced in the first effect. In this double-effect evaporator, 1 lb of steam results in approximately 2 lb of evaporated water, one from each effect.

One can extend the concept and build an evaporator with N effects, delivering N lb of evaporated water per 1 lb of steam. However, there is an upper practical limit, dictated by economics. The total available temperature driving force (ΔT), the difference between the temperature of the steam to the first effect and the evaporation temperature of the final effect, is distributed over all effects. With a greater number of effects, each effect receives a smaller portion of the overall ΔT, and for a given heat-transfer area per effect, the evaporation rate at each effect decreases. Consequently, more effects are needed to achieve a targeted evaporation rate, driving up the required investment. The optimum number of effects is reached when the energy savings no longer supports the increased cost of capital. In most cases, more than five or six effects is difficult to justify. Note that multiple effects do not provide increased capacity over a single-effect evaporator, only reduced energy usage.

By convention, effects are numbered according to the direction of the flow of vapor. The first effect is heated by boiler steam, and effects 2 through N are heated by vapor from effects 1 through $N-1$, respectively. However, the process liquid flow is not necessarily sequential in this manner, as shown in Figure 2 for a four-effect evaporator. In forward flow (Figure 2a), feed enters the first effect, and like the generated vapor streams, the intermediate product from each effect flows to the next one in line. The main advantage is the successive decrease in pressure (corresponding to the decrease in temperature), which either reduces the size of the required interstage pumps, or eliminates the need for them entirely.

In reverse flow (Figure 2b), feed enters the final effect, and each intermediate product flows to the preceding effect, with concentrate removed at the first effect. The advantage is that product streams of increasing concentration are handled at higher temperatures. This counteracts the high viscosity often encountered at higher concentrations, resulting in improved heat transfer and ease of handling. The disadvantage is the need for interstage pumps to overcome the in-

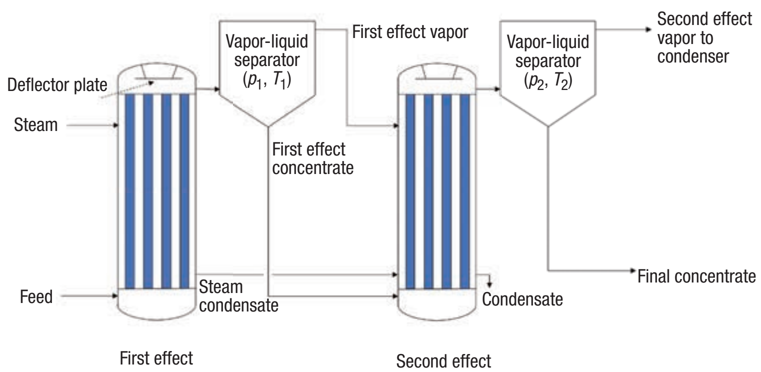

FIGURE 1. This double-effect rising-film evaporator uses the latent heat contained in vapor from the first effect to evaporate additional water in the second effect. More energy is saved by flashing the first-effect steam condensate into the second-effect heat exchanger

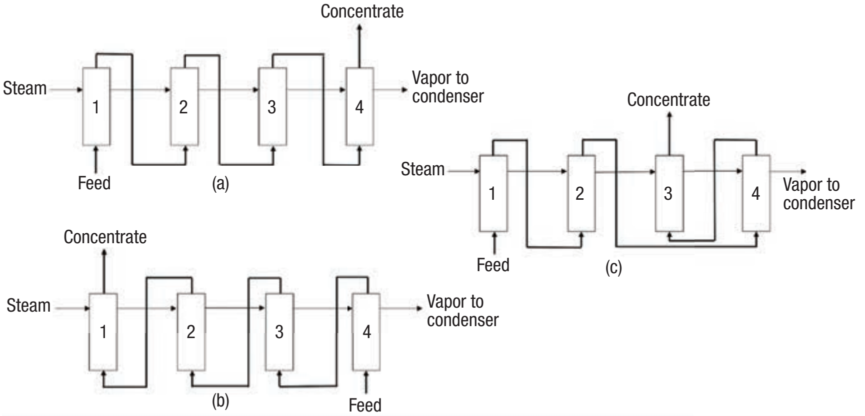

FIGURE 2. By convention, effects of a multiple-effect evaporator are numbered to follow the steam and vapor flow. Options for process material are as follows: (a) forward flow (in the same direction as vapor flow); (b) reverse flow (in the opposite direction of vapor flow); and (c) mixed flow (a combination of forward and reverse flow)

crease in pressure between a given effect and the previous one.

Mixed flow (Figure 2c) may be a reasonable compromise. As in forward flow, feed enters the first effect, and intermediate product streams flow sequentially until effect *k* is reached. Product emanating from effect *k* is directed to the last effect *N*, then product from there flows in reverse, leaving effect (k + 1) as final concentrate. Mixed flow allows some interstage pumps to be reduced in size or eliminated, while still allowing the viscous concentrate to be handled at a higher temperature than with forward flow.

Vapor recompression

Like the use of multiple effects, vapor recompression is a method of capturing the energy contained in the process vapor. This technique comprises compressing the vapor, either mechanically or thermally, then reusing it as heating medium.

Unlike some other evaporator operations, mechanical vapor recompression (MVR) does not employ boiler steam as the heat source (except for a small amount used at startup and as makeup). Instead, the required energy is provided by a compressor, which raises the pressure and temperature of the process vapor high enough for it to serve as the heat source for additional evaporation. A schematic diagram is shown in Figure 3. Note that a condenser is not needed, because all of the vapor is recompressed and reused. Once reused, the vapor is removed as condensate, to be replaced by freshly produced and recompressed vapor. Compressors can be driven by an electric motor, steam turbine, gas turbine or internal combustion engine [*2*, *3*].

Typically, the energy economy of an evaporator with MVR is equivalent to 10 to 15 conventional evaporation effects, although equivalence to 30 effects or more is possible. The economy is a function of the required compression ratio, which in turn depends on the evaporation pressure, the boiling point elevation (BPE; further discussed in Ref. [*1*]), and the required ΔT. Savings are higher when the cost of electrical or mechanical power is low, when low-pressure steam is not available or when the cost of providing cooling water is high. For a reasonable compressor size and power requirement, usually the ΔT is kept in the range of 10 to 18°F. This limitation may lead to the need for a high heat-transfer area, which in turn may increase the cost of an MVR evaporator when compared to a multiple-effect unit with similar capacity. However, this is at least partially mitigated by the omission of steam boiler and cooling tower (or other cooling water source) capacity, which are not needed with MVR [*2*, *4*].

MVR is particularly well suited for film evaporators, because the high heat-transfer coefficients reduce the required ΔT, and in turn, the compression ratio. The technique is not used for high-fouling applications or if the BPE is high, because the higher temperature needed to obtain the necessary ΔT leads to compression ratios that are not economical. These cases may be handled by using MVR in conjunction with a conventional evaporator. For example, the initial concentration may be done with a film evaporator with MVR, then a forced-circulation unit may be used for the final concentration.

Rather than a mechanical compressor, thermal vapor recompression (TVR) uses a steam jet ejector to recompress the process vapor (Figure 4). Unlike MVR, only part of the vapor is recompressed, while the rest is directed to the condenser in single-effect units, or the second effect in multiple-effect evaporators. Because TVR is better suited to vacuum operation than MVR, the former is often preferred for heat-sensitive products that require low temperatures. Similarly, TVR can add some steam economy in applications that cannot use multiple effects because the temperature in the earlier effects would be too high. The ratio of motive steam to entrained vapor depends on the steam supply and the evaporation pressures. As a rule of thumb, a TVR adds the equivalent of one evaporator effect.

TVR offers simplicity of design and construction, low cost, low maintenance, ability to handle large volumes of vapor and the ability to handle corrosive gases. The main disadvantage is lack of operating flexibility, with a rapid decrease in efficiency upon deviation from design conditions. As with MVR, this

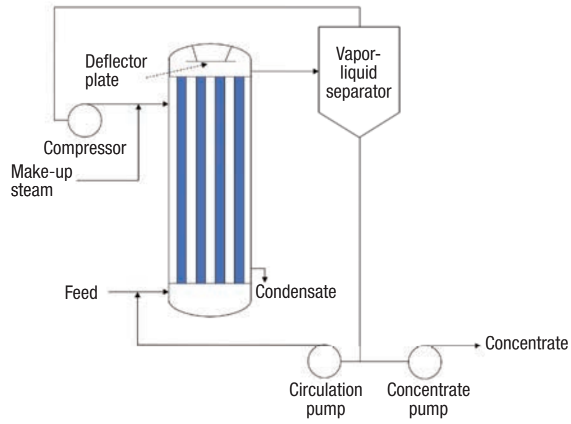

FIGURE 3. This rising-film evaporator uses mechanical vapor recompression, which typically provides steam economy equivalent to between 10 and 15 evaporation effects

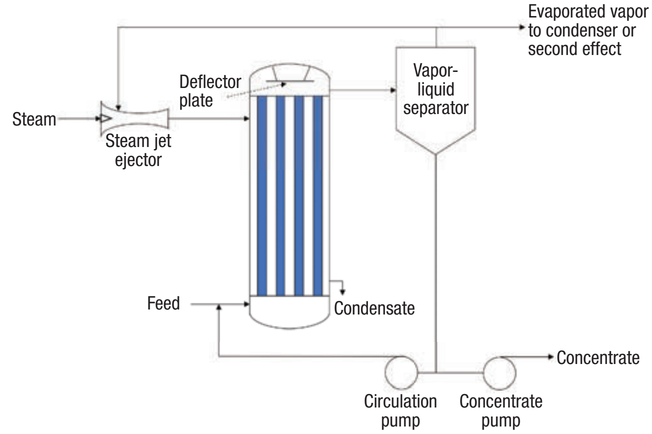

FIGURE 4. Thermal vapor recompression usually increases steam economy by the equivalent of one evaporation effect

precludes high-fouling applications, because conditions would change with the buildup of deposits on the heat-transfer surface. Installations that require more flexibility may use multiple jets in parallel, with valves to match the number of online jets to the targeted flowrate.

Control of evaporators

As with most types of process equipment, there are numerous ways to control an evaporator, ranging from simple to sophisticated. An example of a control strategy that is intermediate in complexity, applied to a falling-film evaporator with recirculation, is shown in Figure 5. The desired steam flowrate is set by the operator, and maintained by virtue of a flow sensor and control valve. Alternatively, steam pressure can be controlled instead of flowrate, using either a pressure sensor and a control valve, or a simple pressure regulator with a spring-loaded diaphragm. The latter is the least expensive, and provides adequate control in many applications. One disadvantage of pressure control, regardless of the method, is the need to increase the setpoint over time as the heat exchanger fouls. This is not necessary when the steam flow, rather than the pressure, is controlled, because the pressure is self-adjusting. That is, the steam pressure increases until the ΔT is sufficient to obtain a heat-transfer rate high enough to condense the steam entering at the controlled flowrate.

Feed flowrate is regulated to keep the vapor-liquid separator level at setpoint, using a cascade loop. Concentrate solids content is maintained at setpoint by controlling the rate at which concentrate is removed, employing a second cascade loop. Solids content can be inferred from sensors that measure, for example, refractive index or density. The former is obtained from an inline refractometer, a relatively inexpensive device. Density can be measured using a gamma-radiation density meter, which relates the attenuation of gamma radiation by the process fluid to its density, and in turn, solids content. While considerably more expensive than other methods, this technique offers high accuracy and no contact with the process fluid.

For the vacuum evaporator shown in Figure 5, evaporation pressure is regulated by a controlled bleed of air (or inert gas). Also, there is no control on the condenser water, only temperature indication. While not shown in Figure 5, some designs include a sensor in the vapor-liquid separator to detect the presence of foam at a pre-determined level, followed by automatic addition of a chemical antifoamer.

While a single-effect evaporator is shown in Figure 5, the same control strategy is applicable to multiple-effect units. Pressures, temperatures and solids contents of the intermediate streams are not controlled, because the operation is self-regulating, but a level-control loop at each vapor-liquid separator may be desirable. Alternatively, separator levels can be controlled by simple overflow through a side port, with the connecting pipe sized to provide sufficient pressure drop so that the downstream pump (if used) suction is not starved. ■

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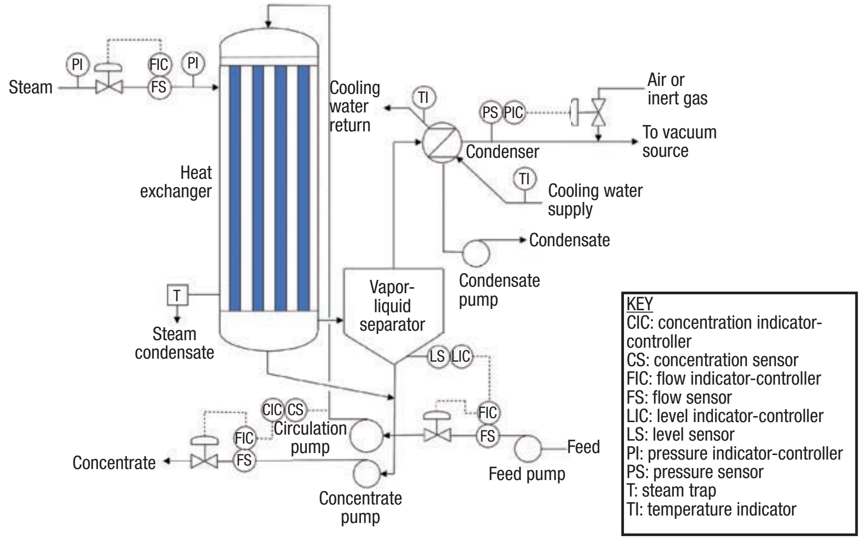

FIGURE 5. An evaporator can be controlled in a variety of ways. Here, the steam flowrate is set manually, the feedrate is regulated to maintain the desired level in the vapor-liquid separator, and concentrate flowrate is varied to maintain the desired concentrate solids concentration

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Economic Indicators

2018 2019 2020

Download the CEPCI two weeks sooner at www.chemengonline.com/pci

CHEMICAL ENGINEERING PLANT COST INDEX (CEPCI)

(1957–59 = 100)	July '20 Prelim.	June '20 Final	July '19 Final
CE Index	593.5	591.1	604.6
Equipment	718.8	715.7	735.8
Heat exchangers & tanks	613.0	610.6	646.8
Process machinery	719.7	719.0	722.2
Pipe, valves & fittings	945.8	934.2	953.9
Process instruments	415.9	411.8	415.4
Pumps & compressors	1083.5	1084.1	1068.2
Electrical equipment	563.1	561.3	558.3
Structural supports & misc.	760.8	764.7	796.4
Construction labor	337.3	335.5	335.6
Buildings	594.2	591.3	593.9
Engineering & supervision	312.2	313.0	314.3

Annual Index:

2012 = 584.6

2013 = 567.3

2014 = 576.1

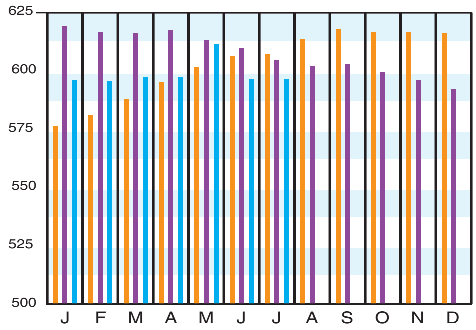
2015 = 556.8

2016 = 541.7

2017 = 567.5

2018 = 603.1

2019 = 607.5



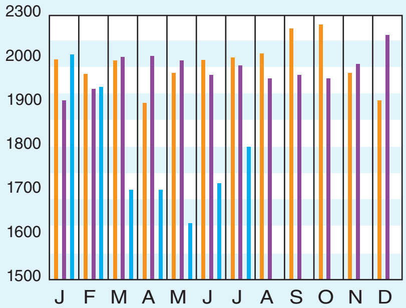
Starting in April 2007, several data series for labor and compressors were converted to accommodate series IDs discontinued by the U.S. Bureau of Labor Statistics (BLS). Starting in March 2018, the data series for chemical industry special machinery was replaced because the series was discontinued by BLS (see *Chem. Eng.*, April 2018, p. 76–77.)

CURRENT BUSINESS INDICATORS

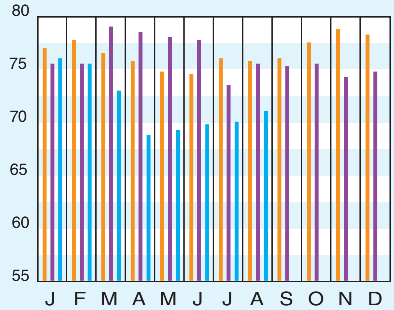
	LATEST		PREVIOUS				YEAR AGO
CPI output index (2012 = 100)	Aug. '20	= 95.2	Jul. '20	= 94.0	Jun. '20	= 92.2	Aug. '19 = 102.9
CPI value of output, $ billions	Jul. '20	= 1,810.1	Jun. '20	= 1,768.1	May '20	= 1,637.2	Jul. '19 = 2,032.0
CPI operating rate, %	Aug. '20	= 70.9	Jul. '20	= 69.9	Jun. '20	= 68.5	Aug. '19 = 76.7
Producer prices, industrial chemicals (1982 = 100)	Aug. '20	= 219.5	Jul. '20	= 217.6	Jun. '20	= 211.9	Aug. '19 = 245.8
Industrial Production in Manufacturing (2012 =100)*	Aug. '20	= 97.9	Jul. '20	= 97.0	Jun. '20	= 93.4	Aug. '19 = 105.2
Hourly earnings index, chemical & allied products (1992 = 100)	Aug. '20	= 189.5	Jul. '20	= 189.8	Jun. '20	= 190.6	Aug. '19 = 185.2
Productivity index, chemicals & allied products (1992 = 100)	Aug. '20	= 99.7	Jul. '20	= 100.6	Jun. '20	= 99.1	Aug. '19 = 97.7

CPI OUTPUT INDEX (2000 = 100)†

CPI OUTPUT VALUE ($ BILLIONS)



CPI OPERATING RATE (%)



*Due to discontinuance, the Index of Industrial Activity has been replaced by the Industrial Production in Manufacturing index from the U.S. Federal Reserve Board.
†For the current month's CPI output index values, the base year was changed from 2000 to 2012
Current business indicators provided by Global Insight, Inc., Lexington, Mass.

CURRENT TRENDS

The preliminary value for the *CE* Plant Cost Index (CEPCI; top) for July 2020 (the most recent data available) increased compared to the previous month's value, reversing a three-month period of decline. Three of the four major subindices — Equipment, Buildings and Construction Labor — rose in July, offsetting a small decrease in the value for the July Engineering & Supervision subindex. The current CEPCI value sits at 1.8% lower than the corresponding value from July of last year. Meanwhile, the Current Business Indicators (CBI; middle) showed increases for both the CPI Output Index and the CPI Operating Rate for August 2020. In addition, the CPI Value of Output rose in July 2020.